ACKNOWLEDGMENTS

The National Airspace System (NAS) Architecture Version 4.0 is the joint product of the national aviation community. It exists today because of a lengthy development process that involved the Federal Aviation Administration (FAA) and every major aviation interest group in the United States.

This architecture is the integrated long-range plan for the NAS, which draws on new technologies and a dedicated FAA workforce to meet the increasing demands on our national air transportation system. It also deals with the realities of ever-expanding aviation travel and commerce and the realities of fiscal constraints. The challenge to develop this plan has been answered—and answered well.

It is impossible to directly credit each person involved with creating the NAS architecture. However, specific organizations inside and outside the FAA were *key* players in its development. They include:

Department of Transportation (DOT), the parent organization of the FAA

FAA organizations—Research and Acquisition (ARA), Air Traffic Services (ATS), and Regulation and Certification (AVR)

External organizations—RTCA, Incorporated; the Research, Engineering, and Development Advisory Committee (REDAC); Department of Defense (DOD); SETA (System Engineering and Technical Assistance contractor (TRW, ARINC, CTA, NYMA, RMS, SAIC, JTA, PMA)); MITRE Corporation/ Center for Advanced Aviation System Development (CAASD); and CSSI.

Special acknowledgment goes to the RTCA Free Flight Steering Committee and its select committee for building consensus on the direction of NAS modernization.

EXECUTIVE SUMMARY

This architecture is an evolutionary plan for modernizing the National Airspace System (NAS) and moving toward Free Flight. It incorporates new technologies, procedures, and concepts intended to meet the needs of NAS users and service providers.

The publication of the *National Airspace System Architecture Version 4.0* marks a major milestone for the Federal Aviation Administration (FAA). The first published version of the NAS Architecture (Version 2.0, October 1996) focused on sustaining existing infrastructure while evolving toward a system that supports Free Flight. Version 2.0 generated over 2,200 comments and initiated discussion about the need for an Air Traffic Services (ATS) concept of operations for a modernized NAS, aviation community needs, stable funding requirements for the FAA, and the required pace of NAS modernization. These issues were debated, with assistance from RTCA and the Research, Engineering, and Development Advisory Committee (REDAC).

Published in December 1997, the draft *NAS Architecture*, commonly referred to as Version 3.0 (V3.0), incorporated feedback from the aviation community; the new ATS document, *A Concept of Operations for the National Airspace System in 2005;* and anticipated funding levels. The draft generated over 1,600 comments. In response, the Administrator formed the NAS Modernization Task Force to examine the remaining NAS modernization issues and risks.

This document, *National Airspace Architecture Version 4.0*, incorporates previous comments; input from the Administrator's Modernization Task Force; and more realistic funding profiles for research, engineering, and development (R,E&D), facilities and equipment (F&E), and operations (OPS). This architecture, which covers the period 1998 to 2015, is based on: (1) the *Government/Industry Concept of Operation*, developed jointly by RTCA and the FAA, (2) ATS's *A Concept of Operations for the National Airspace System in 2005*, and (3) a set of capabilities recommended by the RTCA Task Force 3 Report on Free Flight.

In accordance with the evolutionary development paradigm recommended by RTCA and industry, certain maturing technologies in the architecture are deployed on a limited basis and assessed by the FAA and users. Results of the assessment will be used to modify the technologies, if required, prior to national deployment.

NAS modernization is implemented in three phases.

Phase 1 (1998–2002). Current NAS systems and services are maintained while new systems such as the Standard Terminal Automation Replacement System (STARS), display system replacement (DSR), and Wide Area Augmentation System (WAAS) are introduced.

The NAS Modernization Task Force recommended that a Free Flight Phase 1 Core Capabilities Limited Deployment (FFP1 CCLD) program be implemented to mitigate risk and provide highly desired capabilities at selected locations before the end of 2002. The NAS Architecture Version 4.0 incorporated the FFP1 CCLD program as an initiative to provide early user benefits. FFP1 CCLD will deploy key automation capabilities to a limited number of sites within the NAS for formal evaluation by aviation stakeholders and FAA operators. Each capability will be evaluated for operational suitability and affordability prior to full-scale development or deployment.

To mitigate risk in the communications, navigation, surveillance (CNS) area, many of the ground systems, airborne avionics, decision support tools, supporting procedures, and training needed to provide an integrated set of capabilities will be tested in an operational environment during the Safe Flight 21 and Alaska Capstone programs. The results of Safe Flight 21 will drive national deployment strategies and timing for key CNS technologies.

Phase 2 (2003–2007). This phase concentrates on deploying new CNS and automation technologies to support the concept of operations.

Phase 3 (2008–2015). The required infrastructure for modernizing the NAS will be completed. Automation advancements integrated with new CNS technologies will result in less restrictions and more Free Flight capabilities throughout the NAS.

Capabilities

The NAS will be modernized incrementally. New systems will replace older ones, and new capabilities derived from advanced technologies and/or procedures will be added. The new capabilities will be a result of integrating new systems, airspace changes, procedures, training, avionics, and rulemaking. This architecture identifies and synchronizes the activities necessary for fielding a capability to provide benefits as early as is affordable under current and projected funding.

The following paragraphs describe the evolution of the NAS provided in the architecture by functional and domain areas.

Navigation, Landing, and Lighting Systems. In Phases 1 and 2, the ground-based navigation infrastructure will transition to a satellite-based system that uses the Global Positioning System (GPS) augmented by WAAS and the Local Area Augmentation System (LAAS). This satellite-based navigation and landing architecture will provide the basis for NAS-wide direct routing and guidance signals for precision approaches to most runway ends in the NAS, and it will reduce the variety of navigation avionics required aboard aircraft. Some ground-based navigational systems may be retained to back up satellite-based navigation operations along principal air routes and at high-activity airports.

Surveillance. The NAS architecture calls for evolution from the current primary and secondary radar systems to digital radar and automatic dependent surveillance (ADS). This change is designed to improve and extend surveillance coverage and provide the necessary flexibility for Free Flight. After data from weather radars become available on the new en route controller displays (i.e., DSR), primary radar will be phased out of en route airspace.

A new radar for approach control services (the ASR-11) will include weather-detection capability. The weather capability of the ASR-9 radar will be improved with the addition of the weather system processor (WSP). Primary radars will also be installed at more airports for airport surface surveillance. Secondary surveillance radars (SSR) with selective interrogation (SI) capability will be used in both en route and terminal airspace.

Based on successful Safe Flight 21 demonstrations and better definition of user benefits, users are expected to equip with automatic dependent surveillance broadcast (ADS-B) for air-air surveillance during Phase 1. If users do so, ADS, based on ADS-B, will be implemented during Phase 2 to enhance en route, terminal, and airport surface surveillance. ADS, based on automatic dependent surveillance addressable (ADS-A), is planned to provide surveillance in oceanic airspace in Phase 2.

Communications. The FAA will transition from analog voice and commercial service-provider data link communications to an integrated digital communications capability. Data link communications in Phase 1 will evolve as new applications are tested. Implementation of data link will reduce voice-channel congestion and increase the capacity of each very high frequency (VHF) frequency. During Phase 2, the FAA will begin replacing its analog air-ground radio infrastructure with digital radios (next-generation air-ground communication system (NEXCOM)). The capability of NEXCOM radios to provide digital voice and data communications will be implemented gradually during Phases 2 and 3. Ground-ground operational and administrative communications systems will be combined into an integrated, ground digital telecommunications system.

Avionics. Aircraft are expected to gradually transition to avionics that use satellite technology (GPS WAAS/LAAS) for navigation, landing, and reporting position information to other aircraft (ADS-B) and surveillance systems. The GPS WAAS/LAAS receivers will enable pilots to navigate via direct routes and to fly precision instrument approaches to virtually any runway. Aircraft radios will also be replaced for compatibility with the new, digital air-ground communications infrastructure. New, multifunctional cockpit displays will show the position of nearby ADS-B-equipped aircraft, provide moving map displays, and present data-linked information, such as graphical weather and notices to airmen (NOTAMs). Lengthy transition periods are designed into the architecture to accommodate the varying avionics transition schedules of all NAS users (i.e., airlines, general aviation (GA), and the Department of Defense (DOD)).

Information Services for Collaboration and Information Sharing. Integrated NAS information services will be the basis for operational planning improvements such as receiving and sharing common data and the ability to make joint planning decisions. A systemwide computer network with standardized data formats will allow NAS information services interoperability. The NAS-wide information services will evolve from today's current array of independent systems and varying standards to a shared environment that connects users and service providers for traffic flow management, flight service, and aviation weather information.

Traffic Flow Management. Air traffic management (ATM) encompasses traffic flow management (TFM) and air traffic control (ATC) capabilities and is designed to minimize air traffic delays and congestion while maximizing overall NAS throughput, flexibility, and predictability. TFM is the strategic planning and management of air traffic demand to ensure smooth and efficient traffic flow through FAA-controlled airspace.

TFM capabilities are managed primarily at the Air Traffic Control System Command Center (ATCSCC). Some functionality is distributed to traffic management units at air route traffic control centers (ARTCCs), high-activity terminal radar approach control (TRACON) facilities, and at the highest-activity airport traffic control towers (ATCTs). The Enhanced Traffic Management System (ETMS) will be updated with new tools. For example, the new control-by-time-of-arrival (CTA) tool will give users the capability to determine which flights and departure times are suitable for the capacity at the destination airport. The FAA will provide ground delay program (GDP) data to airline operations centers (AOCs). GDP data include operative airport acceptance rates, which will enable airlines to respond with revised, suitable flight schedules. A further enhancement, interactive flight plan filing, will enable FAA automation systems to provide feedback on system constraints and options to users' flight plans.

En Route. The current ARTCC computer hardware and software infrastructure will be replaced with new hardware, software, and operating systems. During Phase 1, new controller workstations (i.e., DSRs) will be installed and the current Host computer hardware will be replaced with a new computer (the Host/oceanic computer system replacement (HOCSR)) that uses the existing software applications. Controller tools such as conflict probe and the Center TRACON Automation System/Traffic Management Advisor (CTAS/TMA) will be implemented on outboard processors as part of the FFP1CCLD program. During Phase 2, the existing software applications will be recoded and new applications added to support air traffic control functions. During Phase 3, this modern computer infrastructure is expected to support advanced traffic management capabilities that support the movement toward Free Flight.

Oceanic and Offshore. During Phase 1, manual aircraft tracking that currently relies upon verbal pilot position reports will transition to satellite-based position reports received via data link. Communications between oceanic controllers and pilots will also be through satellite data link. During Phase 2, the oceanic infrastructure will be upgraded to use automatic data-linked position reports for automated aircraft tracking. In Phase 3, as the oceanic communications, surveillance, and automation capabilities for air traffic management improve, separation between properly equipped aircraft will continue to be reduced.

Terminal. A combination of ground automation and airborne systems will allow flexible departure and arrival routes and reduce or eliminate speed and altitude restrictions. During Phases 1 and 2, the existing terminal automation system will be replaced with the STARS. During Phase 2, the terminal automation infrastructure will evolve to incorporate new air traffic control functions such as ADS and weather information from the Integrated Terminal Weather System (ITWS). During Phase 3, the hardware and software will be improved to accommodate advanced controller tools such as conformance monitoring, conflict detection, and enhanced arrival/departure sequencing. These tools will enable controllers to maintain clear weather aircraft-acceptance rates at airports during inclement weather conditions.

Tower/Airport Surface. The tower/airport environment will evolve from having minimal automation support to having expanded use of data link, improved surface surveillance displays, and decision support tools. During Phase 1, the initial surface movement advisor (SMA), as part of the FFP1 CCLD initiative, will provide airline ramp control operators with arrival and departure information. New automation systems and increased information exchange among airport operators and users (i.e., airline operations centers, aircraft, and surface vehicles) will be implemented during Phases 2 and 3 to provide dynamic surface movement planning. This dynamic planning enables users and service providers to balance arrivals, departures, runway demand, gate changes, taxi routes, and deicing requirements.

Flight Services. Flight planning information distribution will evolve to provide easier access to information on weather, special use airspace (SUA) status, traffic management initiatives, and NOTAMs. During Phase 1, the current flight service automation systems will be replaced by the new Operational and Supportability Implementation System (OASIS). During Phases 2 and 3, OASIS will be integrated with the NAS-wide information network for improved information sharing.

Aviation Weather. The current NAS standalone weather systems will evolve and become integrated into a weather server so that information is single-source and shared by all systems. Weather information gathered and processed at the servers will be available to users and service providers in a more timely manner, promoting common situtational awareness and enhancing collaborative decisionmaking for controllers, traffic managers, aircrews, and dispatchers. In Phase 1, two key systems will be implemented, ITWS for terminal airspace and the weather and radar processor (WARP) for en route airspace.

Infrastructure Management. The current decentralized method of managing equipment maintenance will be replaced by a centralized method that will expand the FAA's reliance on remote monitoring and restoral of systems. New air traffic control equipment will include remote monitoring and restoral features to support this management strategy. This will enable the FAA to manage the infrastructure nationally rather than regionally and allow users to collaborate on service restoration priorities.

Conclusion

This architecture is a plan for an evolutionary approach to NAS modernization in which current NAS capabilities are sustained or improved while new technologies are introduced. In this architecture, the FAA and the NAS users have identified which technologies are likely to provide significant benefits, how to evaluate them, and when to implement them (contingent on affordability).

The risks associated with some of the new technologies will be mitigated by FFP1 CCLD and the Safe Flight 21 and Alaska Capstone programs, which provide for operational testing in a limited area prior to national deployment. Technology growth, funding levels, and other factors can and probably will affect the course of modernization. As new information arises, the FAA and the NAS users will collectively revise the architecture to refine the course of NAS modernization.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

PART I

INTRODUCTION TO THE NAS ARCHITECTURE

1 PART I INTRODUCTION TO THE NAS ARCHITECTURE OVERVIEW

The National Airspace System (NAS) architecture is an evolutionary plan for modernizing the NAS and moving toward Free Flight. It incorporates new technologies, procedures, and concepts to meet the needs of NAS users and service providers.

The NAS architecture is a result of intense Federal Aviation Administration (FAA) and aviation industry involvement in capturing and restructuring the requirements for a modernized, safer, and more efficient NAS. The NAS architecture describes the system support, operational concepts, schedules, human and physical resources, and other actions essential for maintaining NAS safety, capacity, and performance.

The modernized NAS will offer greater flexibility and functionality through systems that are based on up-to-date technology, information sharing, and common data exchange evolving over time. However, during this evolution, the NAS must be sustained to operate without interruptions.

This architecture is derived from internal and external briefings and reviews by the FAA and industry groups, as well as from thousands of comments on previous releases. The architecture attempts to respond to all comments and concerns, while considering the realities of the anticipated FAA budget constraints over the next 20 years.

Document Organization

The narrative is organized to give readers a comprehensive understanding of the entire architecture and to direct them to a specific portion of the document for more detailed information. References to source information are provided for a more in-depth understanding.

The *Government/Industry Concept of Operations*, Air Traffic Services' Concept of Operations, and the concepts expressed in the Free Flight Action Plan all have had a major impact on the architecture and are referenced throughout the document.

This document is organized into five parts, as shown in Figure 1-1, Roadmap of the NAS Architecture Document. Part I, Introduction to the NAS Architecture, provides an overview and discussion of previous documents and how this document has evolved. It also describes the modernized NAS and how the various users benefit from it.

Part II, NAS Architecture Supporting Elements, covers the evolution of NAS capabilities and the costs of modernization. Additionally, it summarizes the architecture in the following areas critical to successful NAS modernization: Free Flight Phase 1 Core Capabilities Limited Deployment (FFP1 CCLD), Safe Flight 21, and Capstone program descriptions; risk mitigation; safety; human factors; security; research, engineering, and development; regulation and certification; and personnel.

Details of functional area changes are described in Part III, NAS Architecture Description, which introduces the core of the logical architecture. Each section addresses how that portion of the NAS is evolving. The functional area sections appear in the following format:

- Overview
- Evolution
- Summary of Capabilities
- Human Factors
- Transition
- Costs
- Watch Items.

A summary is presented in Part IV. Part V, Appendixes, contains the list of acronyms, participating organizations, references, and the NAS capabilities diagrams and matrix.

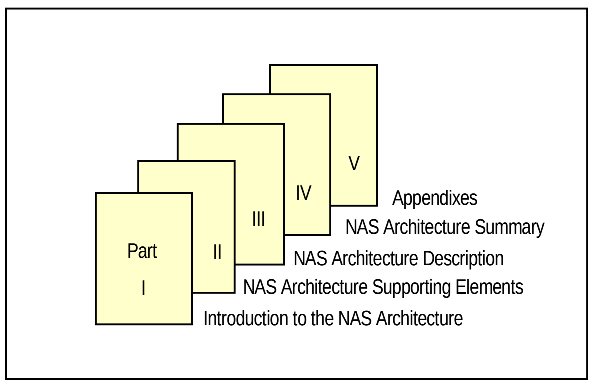


Figure 1-1. Roadmap of the NAS Architecture Document

The FAA understands the business needs and concerns of NAS users and has attempted to address these concerns in the NAS architecture. The architecture is both a planning tool and a “living” document. As needs, technology, and operating concepts change, the architecture will be up-dated to accommodate the impact of those evolving changes.

2 INTRODUCTION

The release of the *NAS Architecture Version 4.0* marks a major planning milestone in the NAS modernization process. For the past 2½ years, the FAA has worked closely with the user community to develop a better understanding of its requirements for a safer and more efficient NAS.

2.1 Developing the Architecture

This architecture has evolved from earlier work. *NAS Architecture Version 2.0*'s release in October 1996 resulted in the submission of over 2,200 comments. After the December 1997 draft *NAS Architecture* (Version 3.0) was distributed, over 1,600 comments were received. All of the comments were considered in developing this architecture. The architecture has been coordinated within the FAA and with the aviation community. Appendix B lists the organizations that participated in the architecture's development. An overview of Architecture Version 4.0, the *Blueprint for NAS Modernization*, was also published in January 1999.

This architecture has been designed to achieve the following principles:

- Enhance overall NAS safety
- Introduce user benefits early and adapt to user needs
- Maintain and enhance existing services
- Modernize in an evolutionary manner using new technologies
- Use standard components, common systems, and common user interfaces wherever possible
- Ensure adequate security of systems and information
- Ensure compatibility across systems by using accepted systems engineering methodologies
- Give users and service providers wide access to NAS information
- Design the system to be adaptable and easily extensible as requirements change and traffic grows
- Make the architecture executable by staying within the FAA's funding projections.

The aviation community wants improved safety and capacity, increased flexibility, more access to airspace, and a larger role in decisionmaking.

Key internal and external events shaped the architecture.

Responsiveness to Customers. The FAA intends to be more responsive to its customers—the NAS users. Users clearly expressed their desire for a NAS that is more efficient and provides more benefits. These views were stated in the RTCA Task Force 3 Free Flight report.[1] The aviation community painted a picture of a NAS that meets its needs for more flexible routes and a larger role in the decisionmaking process that directs NAS operations.

A draft architecture, dated August 7, was provided to the RTCA Free Flight Steering Committee for review and comments. In its response, the steering committee recommended that the FAA release the NAS Architecture Version 4.0 as a baseline for managing NAS modernization. The RTCA response (see comments at the end of this section) provided six general themes and a list of more detailed comments on selected sections of the architecture. Some of the themes are beyond the scope of this document, while other themes require further discussion and consideration within the aviation community. Most of the detailed comments have been addressed in this document; the remaining comments require additional discussion and analysis before they can be incorporated. This work is underway as the FAA addresses the detailed transition steps in NAS modernization.

Modernization Plan. The White House issued Executive Order 13015, which established the White House Commission on Aviation Safety and Security after the loss of Trans World Airlines

1. *RTCA Task Force 3: Free Flight Implementation,* October 1995.

Flight 800. Key recommendations of the commission were: (1) that the FAA should develop a revised NAS modernization plan and set a goal of the modernized system being fully operational nationwide by the year 2005, and (2) that the Congress, the Administration, and users should develop innovative means of financing this acceleration. [2]

Safety. NAS Modernization will enhance safety through more effective risk management in critical areas of the aviation system. Recently, the FAA's focused safety agenda, "Safer Skies," identified high-priority safety concerns. Additionally, the FAA Administrator has established a risk management policy and has implemented safety risk management as a decisionmaking tool within the FAA. Modernization will strengthen safety risk management in several of these high-priority areas by reducing the potential for controlled flight into terrain and runway incursions, improving flow control of approach and landing operations, and providing better weather information.

Security. Another area of great importance to the FAA and the nation is protection of NAS aviation information systems against electronic intrusion and disruption. Information security has become an increasingly important component of the architecture and the modernization effort. A key recommendation of the White House Commission on Aviation Safety and Security was: "The FAA should establish a security system that will provide a high level of protection for all aviation information systems." Eight months later, the President's Commission on Critical Infrastructure Protection restated this recommendation as: "The Commission recommends the FAA act immediately to develop, establish, fund, and implement a comprehensive National Airspace System Security Program to protect the modernized NAS from information-based and other disruptions, intrusions, and attack."

Reform. The FAA recognized that it would need personnel and acquisition reforms in order to implement modernization. Less restrictive personnel policies allow the right talents to be applied to tasks in a more timely fashion. Streamlined acquisition procedures[3] allow new technologies to be acquired and fielded in less time and at lower cost.

Funding. The question of adequate funding levels for modernization was publicly examined. As directed by the Federal Aviation Reauthorization Act of 1996, Public Law 104-264, the FAA Administrator selected Coopers and Lybrand, L.L.P., to conduct an independent analysis of the FAA's budgetary requirements through fiscal year 2002. These results were provided to the National Civil Aviation Review Commission, which was tasked to evaluate the state of the NAS, determine the need and cost of modernization, and provide recommendations on funding sources. The commission's report clearly states that modernizing the aging NAS infrastructure is critically important and that a sufficient, stable funding source for modernization and the FAA must be identified.

Concepts of Operations. Two concepts of operations were a result of discussions between users of NAS services and FAA service providers. The FAA Air Traffic Services (ATS) organization's *A Concept of Operations for the National Airspace System in 2005* was distributed, followed by the *Government/Industry Concept of Operation,* developed jointly by RTCA and the FAA. Together, the concepts of operations define the capabilities and services needed in a modernized NAS and provide the general time frame for each capability. In this architecture document, the two concepts of operations (i.e., ATS's and the government/industry's) are *jointly* referred to as the CONOPS. This is possible because one is from a service provider perspective, the other reflects the user's perspective.

The labor agreement with the National Air Traffic Controllers Association (NATCA) in late 1998 reclassified air traffic control facilities. The effects of this reclassification on the total number of controllers required, and their salaries, have not been considered in the NAS Architecture Version 4.0.

Modernization Task Force. After distributing the draft *National Airspace Architecture 1997* (Version 3.0) in December 1997, the Administrator formed the NAS Modernization Task Force.

2. *White House Commission on Aviation Safety and Security, Final Report,* February 12, 1997, p. 20.
3. Federal Aviation Administration Acquisition Management System, June 1997.

The Task Force was charged with closing the gaps between the FAA and the aviation community's positions on the risks of NAS modernization. After consulting with industry (through RTCA), the Task Force concluded that users want the benefits of certain key technologies sooner than originally planned for in the NAS Architecture Version 3.0. The Task Force also recommended that users play a larger role in evaluating the potential benefits of modernization. This resulted in the formation of the Free Flight Phase 1 Core Capabilities Limited Deployment (FFP1 CCLD) program, which is discussed in Section 6.

The NAS architecture balances the capabilities requested by users and service providers, the funding level and sources that are expected to be available for modernization, the cost to users and their ability to equip, and the FAA's ability to manage the changes needed to make modernization a reality. Although other architectures are possible, Version 4.0 represents a plan based on a balance between needs and available resources.

2.2 Overview of the NAS

Today's System. Today's NAS is based on traffic patterns of the past, operations of a regulated industry, and information that is isolated by the limitations of obsolete computers. Additionally, accommodating the growth in air traffic is constrained by navigation and air-ground communications spectrum congestion.

Above all, the entire NAS is aging rapidly. Other countries, especially those without a major investment in an existing infrastructure, have already begun using modern technology for their aviation systems. This architecture will be in harmony with the global community. It is the goal of this architecture and the continuing architectural process to provide the roadmap for making our aviation system the safest, most cost-effective, and efficient system possible for the resources available.

The NAS is a complex collection of systems, procedures, facilities, aircraft, and people. The NAS includes thousands of pieces of equipment in hundreds of locations throughout the United States. These components comprise one system that ensures safe and efficient operations (see Figure 2-1). Thousands of people operate the equipment used to provide NAS services to the aviators and passengers who travel each day. The 18,000 plus airports in the United States are also a significant part of the NAS, particularly the more than 3,300 airports that are the core of the national transportation system and receive grants under the Airport Improvement Program. Airports of national importance include all commercial service airports, all reliever airports, and selected general aviation airports.

The main NAS users are air carriers, air cargo, commuter air carriers, air taxis, general aviation, the military, and civilian government. Air carriers conduct scheduled and nonscheduled operations using aircraft weighing more than 7,500 pounds and with 9 or more seats. Commuter air carriers conduct scheduled operations using aircraft weighing less than 7,500 pounds and with less than 9 seats. Air taxi operators are air carriers who conduct on-demand instead of scheduled operations. Air cargo flights carry freight and packages but not passengers. General aviation (GA) includes private pilots, business aviation, and all civilian operations not included above. A wide spectrum of government operations includes military aircraft, the Coast Guard, the Department of Justice, and other government agencies.

Each user group has special needs that must be balanced within the architecture. Commercial operations account for about 95 percent of aviation's impact on the economy.[4] There are over 260,000 GA pilots. The Department of Defense (DOD) has the world's largest fleet, with more than 16,000 aircraft.

As a plane departs the airport, tower, terminal, and en route controllers ensure that it does not conflict with other traffic during its climb to cruising altitude. The en route controllers ensure separation is maintained while en route to the destination airspace where the aircraft is once again controlled by terminal and tower controllers for arrival and landing. Figure 2-2 graphically depicts the various NAS domains.

Navigation systems provide position information to aircraft during flights and for landings. The

4. *The Economic Impact of Civil Aviation on the U.S. Economy, Update '93*, Wilbur Smith Associates, April 1995.

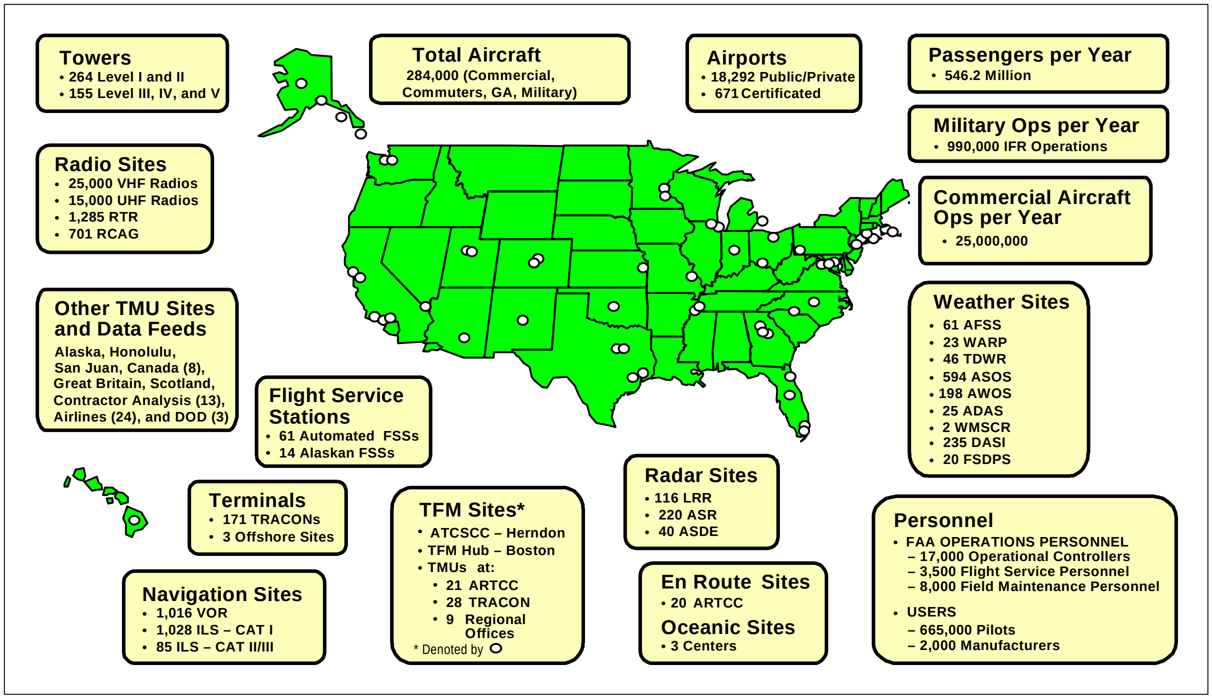


Figure 2-1. The NAS

The NAS is a complex collection of systems, procedures, facilities, aircraft, and people. These components work together as one system to ensure safe and efficient operations.

FAA uses radars to provide surveillance data (i.e., aircraft position) to controllers.

Automation systems assist controllers at oceanic, en route, terminal, and tower locations. Radios allow pilots and controllers to communicate, enabling safe and efficient operations.

Flight service stations (FSSs) assist GA pilots to plan and file flight plans. Airline operations centers (AOCs) work closely with traffic flow managers to plan commercial flights. Planning functions help pilots account for weather and winds along their intended routes and also help the FAA ensure that the demand is balanced for safe operations.

2.3 Modernizing the NAS

Key goals of modernizing the NAS are to provide existing services more efficiently and to provide new services and capabilities that will move the NAS toward a new type of operating environment known as Free Flight.

These goals must be achieved under two constraints: safety will not be compromised, and annual costs to the FAA and users must be kept at a reasonable level.

Service providers and service users interact with each other at three levels: a strategic level (e.g., an airline decision to establish an east coast hub); an operational level (e.g., an airline decision on which city to select for that hub—along with the routes, equipment, and frequency and time of service); and a tactical level (e.g., day-to-day decisions—both on the ground and in the air—on the operation of the hub regarding weather, equipment outages, and known traffic delays).

Given the complexity of the system, the FAA seeks to maintain a flexibility that allows users to achieve individual objectives. The objectives of an airline's operations may be much different from those of GA or DOD operations.

This complexity also is why modernization requires the active participation of all parts of the FAA and user communities. Modernizing even a single NAS function, such as navigation, affects FAA organizations and a broad range of users.

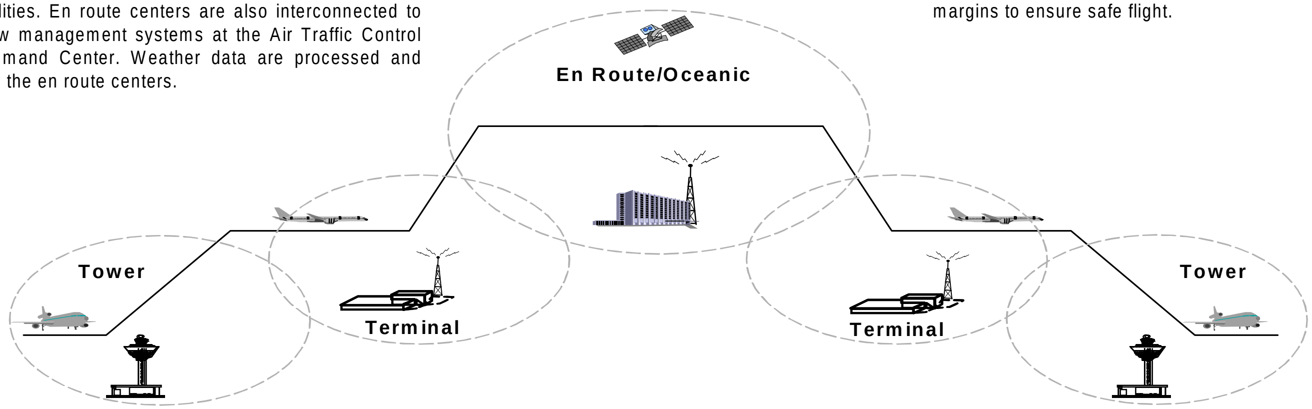
Figure 2-3 illustrates the complexity of the process and the interactions and activities needed to achieve modernization.

En Route

Twenty en route centers control domestic air traffic not specifically delegated to an oceanic, terminal, or tower control facility. The airspace extends out to 100 miles beyond the United States coastlines and its borders with Canada and Mexico. The en route centers operate the computer suite that processes radar surveillance and flight planning data, reformats it for presentation purposes, and sends it to the displays used by controllers to track aircraft. En route centers control the switching of voice communications between aircraft and the center as well as between the center and other national airspace facilities. En route centers are also interconnected to the traffic flow management systems at the Air Traffic Control System Command Center. Weather data are processed and distributed by the en route centers.

Oceanic

The oceanic air traffic control centers control aircraft over portions of the Atlantic, Arctic, and Pacific oceans. Two oceanic centers are co-located with en route centers in New York and Oakland, while a third is located at Anchorage, Alaska. The air traffic control provided over the ocean is substantially different from that provided over land, because there are no surveillance systems that can provide exact aircraft position. Position reports based on on-board aircraft navigational systems are radioed to the controller. Due to the uncertainty in position report reliability, planned overseas flight tracks must provide greater separation margins to ensure safe flight.



Tower

Tower controllers manage and control the airspace within approximately five miles of an airport, including taxiways and runways on the ground. Tower controllers control ground operations on airport taxiways and runways and departing and landing traffic. Towers are provided with flight planning information by the en route computer suite. Weather information is available from the weather processing and distribution communications network.

Terminal

Terminal facilities provide air traffic control services for an air space located approximately 5 to 40 miles from an airport and usually below 10,000 feet in altitude. The terminal controller establishes and maintains the sequence and separation of aircraft taking off, landing, or operating within the terminal airspace. Terminals are interconnected with local towers and provide surveillance and position data of aircraft under terminal control to specialized displays within the tower. Selected terminal facilities are interconnected to the traffic flow management systems at the Air Traffic Control System Command Center. Flight planning information is provided from the en route computer suite. Weather data are provided from the weather processing and distribution communications network.

Figure 2-2. NAS Functional Domains

2.4 Free Flight

The main objective of NAS modernization is moving the NAS towards a new type of operating environment known as Free Flight.

The RTCA defines Free Flight as:

“. . . a safe and efficient operating capability under instrument flight rules in which the operators have the freedom to select their path and speed in real time. Air traffic restrictions are imposed only to ensure separation, to preclude exceeding airport capability, to prevent unauthorized flights through special use airspace, and to ensure safety of flight. Restrictions are limited in extent and duration to correct the identified problem. Any activity which removes restrictions represents a move toward Free Flight.”[5]

Users will derive benefits from the removal of current air traffic control (ATC) constraints and restrictions to flight operations. The benefits will be reflected in an operational environment that provides more efficient management of airspace and airport resources through better information exchange and collaborative decisionmaking among users and service providers.

Under the current system, users file flight plans along FAA-defined air routes determined by a system of ground-based navigational aids (Navaids); however, significant “free flight” area navigation (i.e., more direct routing) takes place above Flight Level 290 through the National Route Program.

The lack of flexibility of the current NAS is due to the inherent constraints of the older technologies used for communications, navigation, surveillance, computer systems, and decision support aids. The future NAS will include new technologies that support capabilities that will allow users and providers more flexibility in planning and in flight operations.

A key benefit to users will be their ability to select and use efficient flight profiles, a key aspect of Free Flight. The combination of cockpit technol-

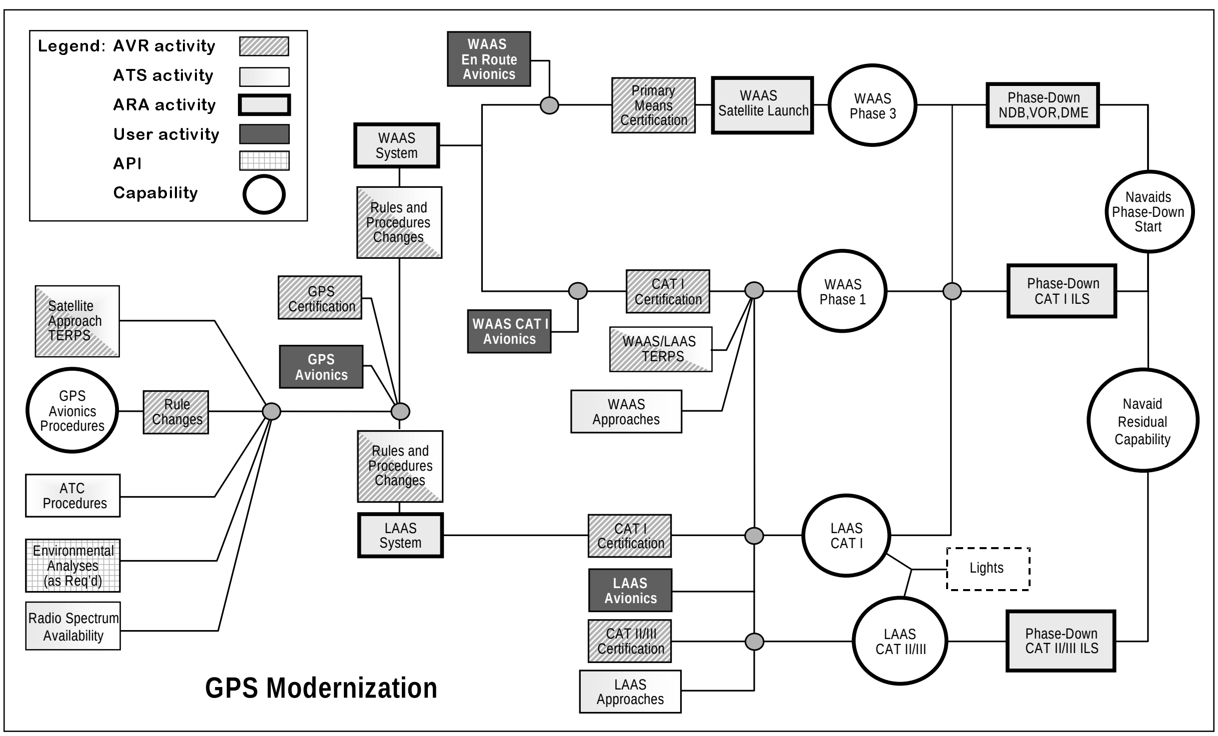


Figure 2-3. Modernization is an Aviation-Community-Wide Task

Deploying new systems, although a significant and critical step, is not sufficient to enable new capabilities and services. New procedures, new avionics, new rules, and public hearings are all integral to NAS modernization. The FAA and user community must work together to realize the benefits of a modernized NAS.

5. Free Flight Action Plan Update, April 2, 1998, pp. 2-3.

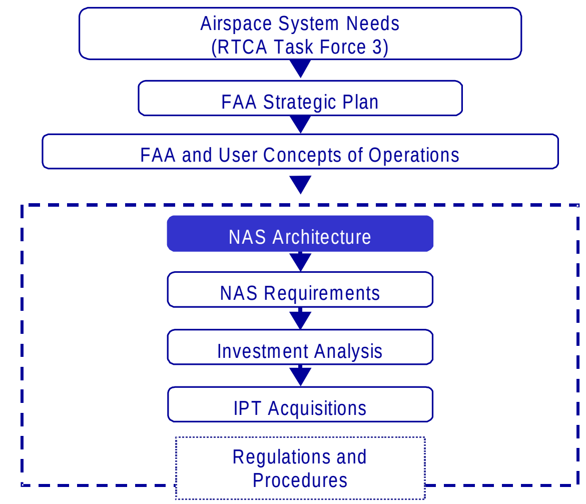


Figure 2-4. The NAS Architecture in Context

A logical architecture, based on the FAA and the Government and Industry Concepts of Operations, the architecture defines the path for NAS modernization. The architecture's approach to modernization strikes a balance between the desires of NAS users, available funding, safety, and the speed at which transitions can occur.

ogy and satellite-based navigation will enable users to fly optimized climb profiles, and the most efficient cruise speeds, altitudes, and routes. Flight planners and pilots will be able to select the most fuel-efficient routes based upon winds aloft and fly optimal descent profiles to the destination airport.

2.5 Role of the Architecture in NAS Modernization

The NAS architecture is the aviation community's roadmap for modernization. It describes the schedules and costs necessary to implement the capabilities and services defined in the CONOPS.

Figure 2-4 depicts the relationship between the Architecture and more strategic documents. Section 11, Regulation and Certification Activities Affected by New NAS Architecture Capabilities, discusses the architecture's regulatory impact.

The NAS Architecture Version 4.0 is a logical architecture. It provides a high-level description of NAS capabilities and services, the functions to be performed, their dependencies and interactions, and the information flow to support these functions. This architecture contains:

- The timing of functional enhancements and operational capabilities
- A sequence of infrastructure improvements
- FAA costs projected for research, engineering, and development (R,E&D); facilities and equipment (F&E); and operations (OPS) budgets, including:
  – System acquisitions
  – Personnel
  – Infrastructure sustainment
- User cost estimates and schedules for equipage (air carrier, regional/commuter, GA, and military).

2.5.1 Using the Architecture Within the Aviation Community

The NAS architecture represents the FAA's commitment to the aviation community. It spells out in detail the vision that the FAA has for the modernized NAS, based on expected funding. It specifies the steps along the modernization path and the time frames for each. It shows FAA products, such as new systems or new capabilities provided by a combination of systems. The architecture also serves as a planning tool for the users of the NAS.

The FAA is working diligently to further understand the users' current aviation service needs.

Major capital purchases, such as avionics, require long lead times.

The architecture is a mechanism for continuing dialog on NAS modernization between the FAA and users.

The transition schedules in Version 4.0 assume a dual operations period of 5 years or more for avionics equipage. As navigational services are transitioned to satellite-based service, the FAA will coordinate with users before finalizing the schedules for phasing down Navaids or discontinuing ground-based services.

The architecture provides direction and challenges for research and development from now through 2015. The architecture is a plan for investigating benefits, examining alternatives, and developing applied technologies and procedures to meet the needs of aviation.

Finally, the architecture serves as a mechanism for a continuing dialog between the FAA and NAS users and becomes the point of departure for further refinement of NAS modernization requirements. The success of the process depends on user involvement.

2.5.2 Using the Architecture Within the FAA

Establishing long-range goals is a key element of the FAA's strategic planning process. The architecture provides a basis for the agency's mission analysis and program planning and defines specific strategic objectives to be achieved by 2015.

After extensive coordination within the FAA and the user community, the Joint Resources Council (JRC)[6] approved the NAS architecture and designated it as "baseline planning guidance" for the agency.

As illustrated in Figure 2-5, the architecture plays an important role in the FAA's new acquisition management system (AMS). The architecture describes the resources needed to modernize the NAS and meet user and service provider requirements. It identifies the required timing and numerous links that tie various programs together. Associated costs have also been estimated.

Funding requirements in the mid term and beyond will be used as starting points for future investment analyses. The JRC can use the architecture as a point of departure for mission need and in-

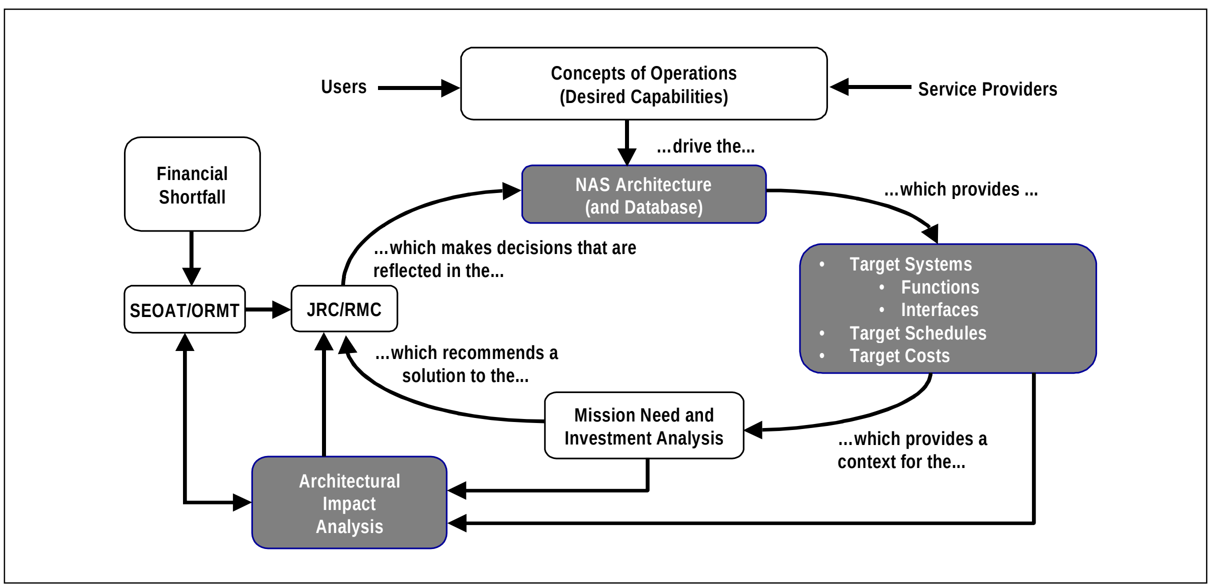


Figure 2-5. The NAS Architecture and the Acquisition Management System

The architecture provides the context for all FAA decisions. It enables decisionmakers to establish priorities and to understand how individual decisions affect the NAS.

6. The JRC is the FAA's top investment decision group.

vestment decisions. Plans made by the JRC or the Administrator and decisions affecting investments will be incorporated into the architecture, and changes will be made as required. User input to the architecture process will continue.

The architecture provides the context for investment analysis, with cost, schedule, and functional targets as starting points. It highlights the interdependencies of functions and capabilities. Although the architecture provides one candidate technical alternative to be analyzed, the investment analysis process may consider and select other alternatives. It provides a framework to use in assessing the implications of various alternatives and the implications of changes in funding, schedule, or functional targets.

This architecture is not an end state. Rather, it will continue to evolve based on the results of projects like Safe Flight 21, the availability of new technologies, new user and service provider requirements and priorities, and funding. Work continues to identify the new capabilities, systems, and activities required to modernize the NAS and achieve Free Flight. Funding requirements continue to be developed and validated. Production and installation schedules continue to be integrated to ensure that the various elements—including regulation and certification activities, new systems, user equipage, and procedural changes—are brought together at the correct time to provide benefits to users.

2.6 Near-Term Risk-Mitigation Activities

Modernizing the NAS will involve technology and cost risks. Some of the new technologies that may be used during modernization have not been tested or proven in an operational environment. Of equal significance are the new procedures that the Free Flight operational concept envisions. Important new controller decision support tools and aircraft air-air separation are two examples of new capabilities that require testing and validation prior to implementation. Three key risk-mitigation strategies the architecture will use are Free Flight Phase 1 Core Capabilities Limited Deployment (FFP1 CCLD), Safe Flight 21, and Capstone.

2.6.1 Free Flight Phase 1 Core Capabilities Limited Deployment

FFP1 CCLD incorporates guidance provided by the NAS Modernization Task Force. FFP1 CCLD is intended to provide early user benefits and mitigate technical risk by implementing key automation capabilities at specific sites within the NAS, for evaluation by aviation stakeholders and FAA operators. The deployments will allow computer-human interface (CHI), training, and safety factors to be evaluated. After the FAA and users have gained experience and evaluated the individual FFP1 CCLD capabilities, decisions will be made on whether to deploy them to additional locations.

2.6.2 Safe Flight 21

Many of the new technologies identified for modernization have been demonstrated in the laboratory or on a limited scale, but their true benefits and costs have not been conclusively established. These demonstrations, while instructive, have not been compelling enough to convince most NAS users to equip with modern avionics. Safe Flight 21 provides the opportunity to take these activities to the next logical step—full operational demonstration and validation, where significantly more accurate user and service provider cost-benefit assessments can occur.

Safe Flight 21 deploys and evaluates certain air traffic control systems and avionics, which use new communications, navigation, and surveillance technologies for determining technical risk and operational suitability. These new technologies include applications such as automatic dependent surveillance broadcast (ADS-B) for air-air and air-ground surveillance and flight information services via data link. Avionics, certification, and procedural development are cost and schedule risks that must be mitigated. Additionally, user benefits must be conclusively proven before avionics and associated ground equipment capital investments can be made.

2.6.3 Capstone

The FAA Alaskan Region's Capstone Program of infrastructure modernization will provide and validate safety and efficiency improvements recommended in the NTSB Safety Study *Aviation Safety in Alaska*. Capstone focuses on safety by improving infrastructure in Bethel and the surrounding area, a small portion of western Alaska. It will address the operating environment and aviation infrastructure, weather observations and recording, airport condition reporting, and adequacy of the current instrument flight rules system.

2.7 Summary

This architecture is a joint plan of the FAA and NAS users on how to modernize the NAS. Today's NAS, while safe and efficient, can be improved significantly through use of new technologies and operating procedures. Successful modernization depends on effective continuous FAA and NAS user planning as well as their mitigation of the risks of new technology.

This document describes how the NAS will evolve consistent with the *Government/Industry Concept of Operations* and the FAA's *A Concept of Operations for the National Airspace System in 2005*.

2.8 Detailed Comments on Architecture 98 From RTCA Free Flight Select Committee

The following pages present the RTCA Free Flight Steering Committee letter and comments on the draft Architecture 1998.

RTCA

RTCA, Inc.
1140 Connecticut Avenue, N. W., Suite 1020
Washington, D. C. 20036

Telephone 202-833-9339
Facsimile 202-833-9434

December 10, 1998

The Honorable Jane Garvey
Administrator
Federal Aviation Administration
800 Independence Avenue
Washington D.C. 20591

Dear Mrs. Garvey,

The Free Flight Steering Committee applauds the FAA's substantial effort to develop and document a single, coherent plan for NAS modernization. As we all agree, the main purpose of this architecture is to document a plan on which both the FAA and the users can base investment decisions. We encourage the FAA to publish Architecture 4.0, thereby setting the baseline for managing NAS modernization activities and reaping the many programmatic benefits that will accrue therefrom. We also encourage FAA to continue working closely with the entire aviation community to move the very important modernization effort forward.

A number of themes emerged as we consolidated our views about the architecture. They are captured in the attachment, along with more detailed comments and concerns about selected sections of Part III, NAS Architecture Description. As a way to underscore FAA's past and continuing commitment to modernizing the NAS as a collaborative, government / industry endeavor, we request that you include this letter and the attachment as part of the published architecture package.

We appreciate the opportunity to work closely with your management team to address the issues we have identified. This collaboration will greatly enhance our collective chances of success. We recognize that such a process is new to all of us and creates new institutional challenges for you. We take our role seriously and will remain responsible and constructive in our feedback.

Sincerely,

Robert Baker
Co-Chair
Free Flight Steering Committee

Monte P. Belger
Monte Belger
Co-Chair
Free Flight Steering Committee

Attachment
Detailed Comments on Architecture 4.0

"Requirements and Technical Concepts for Aviation"

Detailed Comments on Architecture 98 from
RTCA Free Flight Select Committee

A number of themes emerged as the RTCA Free Flight Select Committee reviewed and consolidated comments into a single package. They are presented below:

1. The steps in the plan need to be more benefits-driven. Motivation for user equipage, for example, is not addressed adequately. The document should describe the link between each increment of operational capability and enabling technologies and its associated benefits.
2. Issues related to transition from one step to the next, such as mixed equipage, are not addressed adequately. It is difficult to discern a series of discrete steps from this document. The architecture does not define activities necessary to move between consecutive steps.
3. The architecture should acknowledge throughout, where appropriate, that lessons learned from ongoing experiments and initiatives (e.g., Safe Flight 21) will be integrated into the architecture and will drive technology and other related decisions.
4. The year 2005 needs to be defined as a milestone, describing all components that will be in place. This description should match the FAA and the Government/Industry Operational Concept for 2005. Further, the FAA should continue to apply beyond Free Flight Phase 1 the evolutionary development paradigm that industry / RTCA has recommended.
5. A chapter on Airspace should be included. Airspace is a critical national resource that must be optimized in order for the NAS to gain full benefit from programmed infrastructure enhancements, emerging technology initiatives, and procedural changes that support the transition to Free Flight.
6. The relatively high risk of implementing automation (hardware and software) infrastructure is not addressed adequately.

Following is a list of more detailed comments about selected sections of the Architecture.

SECTION 15 - Navigation and Landing

- Architecture should clarify how phasing down of ground navigation aids will be accomplished
- Sole means issue should be resolved and policy documented in the architecture

SECTION 16 - Surveillance

- Policy should be clearly stated
- Transition path is not clear and needs to be described
- Architecture should address how a mixed equipage environment will operate, and how users will be motivated to equip
- Technology decisions, such as Mode-S, should be based on the results of the RTCA Surveillance subgroup and of Safe Flight 21.

SECTION 17 – Communications

- Architecture should acknowledge that industry is on record as not endorsing VDL Mode 3
- Architecture should acknowledge the CDPCL Build 1 program and describe how lessons learned will be incorporated into the NAS

SECTION 18 - Avionics

- Human factors, certification, equipage and transition issues are not adequately addressed

Detailed Comments on Architecture 98 from
RTCA Free Flight Select Committee

SECTION 19 - NAS Information Architecture

- Architecture should acknowledge that NAS Information Architecture encompassed more than CDM
- Data ownership and security issues should be addressed, and FAA policy stated

SECTION 20 - TFM

- Architecture should clearly distinguish TFM from NAS Information Architecture and CDM
- Architecture uses CTAS terms interchangeably. It should include clear definitions of the following terms/programs: CTAS, TMA, pFAST.

SECTION 21 - En Route

- Incremental, evolutionary development should be incorporated as the basic development philosophy so that enhancements of both capabilities and infrastructure can be adequately addressed.

SECTION 22 - Oceanic

- Architecture should acknowledge alternative acquisition strategy being considered for the ocean.

SECTION 23 - Terminal

- Architecture should acknowledge that STARS is a major risk area, and should define a risk mitigation strategy
- Architecture uses CTAS terms interchangeably. It should include clear definitions of the following terms/programs: CTAS, TMA, pFAST.

SECTION 24 - Tower/Surface

- Architecture should acknowledge the Safe Flight 21 Program, and indicate that lessons learned in ADS-B experiments will be fed into the Architecture.

SECTION 25 - Flight Stations

- Architecture should better define transition benefits and the role of the private sector in the evolution of Flight Service Station Services.
- It should be clearly stated what role commercial services are to play in providing weather data

SECTION 28 - Airports

- Consider deleting this chapter. Most of what is covered is covered in other chapters on Terminal and Surface Operations. Other aspects of airports are outside the scope of the FAA's Architecture

PART II

NAS ARCHITECTURE

SUPPORTING ELEMENTS

3 PART II NAS ARCHITECTURE SUPPORTING ELEMENTS OVERVIEW

Part II and Part III describe the concept of how a modernized NAS would operate based on the principles published in the *Government/Industry Concept of Operations* and *A Concept of Operations for the National Airspace System in 2005* (referred to jointly as the CONOPS). A brief discussion of each section in Part II follows.

Based on the CONOPS, operations within the NAS will change as the NAS is modernized. Section 4, NAS Operations, summarizes the NAS architecture from the user/pilot perspective, with a generalized description of flight operations and potential user benefits in a modernized NAS.

To ensure safety, new capabilities will be implemented incrementally. Section 5, Evolution of NAS Capabilities, defines the three NAS modernization phases and summarizes the enhanced and new capabilities available to air traffic service providers and users. Appendix D provides detailed capability drawings and a matrix for each NAS modernization time period, by phase of flight.

The FAA recognizes that modernization has a variety of technology and acquisition risks. Section 6, Free Flight Phase 1, Safe Flight 21, and Capstone, describes the programs that comprise the NAS modernization risk-mitigation effort. The programs evaluate new technologies and procedures in an operational environment to reduce implementation risks and identify user benefits. The results will serve as a basis for user/provider decisions on national deployment.

During NAS modernization, the FAA's highest priority is to ensure that the safety of the air traffic control system is improved. Section 7, Safety, describes how safety will be improved through incremental implementation of new systems, controller automation tools, and new cockpit avionics.

Because NAS operations are so complex, it is important, from a safety and workload perspective, to understand the human factors implications of changes to the NAS. Section 8, Human Factors, outlines the approach that will be used to: (1) develop or improve human interfaces with the system; (2) optimize human/product performance during system operation, maintenance, and support; and (3) make economic decisions on personnel resources, skills, training, and costs.

The FAA must maintain a system that includes both physical and information security. Section 9, Information Security, outlines the security issues and approaches required to protect new information-based systems while increasing data exchange with external users. This section also addresses the increasing dependence on commercial, "open" systems and the urgency of protecting NAS data availability, integrity, confidentiality, and authenticity. Physical security is an enabler of information security; Section 29, Facilities and Associated Systems, provides more information on physical security.

It is important for the FAA and the users to mutually understand the impact of emerging technologies before they are implemented. Section 10, Research, Engineering, and Development (R,E&D), describes the R,E&D program and its relationship to the NAS modernization process.

Standards and certification of new avionics, procedures, or systems is fundamental to maintaining the safety and interoperability of the NAS. Section 11, Regulation and Certification Activities Affected by New NAS Architecture Capabilities, discusses some of the FAA's processes used to carry out the regulatory and certification mission. This section contains a preliminary analysis of the regulations that will need to be revised and/or expanded to accommodate NAS modernization.

As in most major service organizations, personnel are the FAA's primary and most costly asset. Section 12, Personnel, discusses the costs and overall staffing levels by budget categories.

The overall resource requirements of a plan must be understood before it is implemented. Section 13, Cost Overview, discusses the costs associated with modernization for three types of funding: R,E&D; facilities and equipment (F&E); and operations (OPS). The costs associated with the Airport Improvement Program (AIP) are not addressed in the architecture at this time.

4 NAS OPERATIONS

This architecture is based on designing a NAS that provides the level of services set forth in the joint Government/Industry operational concept and the Air Traffic Services (ATS) concept of operations (referred to jointly as the CONOPS). Both concepts of operations were coordinated with the user community and take advantage of current and emerging technologies to advance NAS operations towards Free Flight. NAS efficiency is increased while safety is enhanced by incorporating new communications, navigation, and surveillance concepts with advanced automation that provides enhanced decision support tools. This section details the NAS evolution from its current state toward one of Free Flight.

4.1 Concept of Operations

The Government/Industry Select Committee for Free Flight Implementation prepared a report that outlines a user and service provider[1] program and delineates activities for implementing the concepts and capabilities of Free Flight. The report, *Government/Industry Operational Concept for Free Flight*, presents a joint perspective of the concept of operations (CONOPS)[2] and potential procedures and technologies for achieving these capabilities. It is intended to serve as the basis for an incremental and benefits-driven approach toward Free Flight. Free Flight allows aircraft operators to choose routes, speeds, altitudes, and tactical schedules in real time, thus improving air travel. Free Flight, which combines the flexibility of visual flight rules (VFR) with the safety (traffic separation capabilities) of instrument flight rules (IFR), will offer significant potential savings in both fuel and flight time.

The ATS CONOPS, described in *A Concept of Operations for the National Airspace System in 2005*, presents the service provider perspectives on NAS operations. It also incorporates International Civil Aviation Organization (ICAO) communications, navigation, and surveillance/aeronautical telecommunications network (CNS/ATN) concepts. By implementing these concepts, the NAS will evolve to meet user needs for greater flexibility and predictability and increased efficiency. Before this operational concept can be implemented, procedures and technologies must be further developed and validated, with an emphasis on human operator considerations.

The CONOPS proposes new or improved NAS capabilities and services, new facilities and equipment, and new roles for controllers, maintenance personnel, and managers. Understanding the capabilities and limitations of controllers, maintenance personnel, and pilots in current and future NAS configurations is critical to the success of the NAS modernization.

The CONOPS is the basis for procedural, investment, and architectural decisions on the operational capabilities and services required to achieve Free Flight.[3] These operational concepts are the first steps of implementing far-reaching concepts in the evolution toward a Free Flight environment and do not describe an end-state system.

4.2 Flight Planning

To support a strategic flight planning process, a NAS-wide information network must distribute timely and consistent information for both user and service provider planning. This information network will provide a greater exchange of electronic data and information between users and service providers—while simultaneously reducing workloads. The flight planning process will

1. The term "service provider" refers to anyone who provides separation assurance, navigation/landing services, aviation information, search and rescue, or other assistance to NAS users. The terms "user" and "NAS user" refer to anyone who uses the air traffic system, specifically air carriers, general aviation (GA), and the Department of Defense (DOD).
2. In the architecture, the term CONOPS applies to both the *Government/Industry Operational Concept for Free Flight* and Air Traffic Services *A Concept of Operations for the National Airspace System in 2005.* When a specific one is referred to, it is called out in the text.
3. Free Flight is defined as a "safe and efficient flight operating capability under instrument flight rules (IFR) in which the operators have the freedom to select their path and speed in real time. Air traffic restrictions are only imposed to ensure separation, to preclude exceeding airport capacity, to prevent unauthorized flight through special use airspace (SUA), and to ensure safety of flight." Restrictions are limited in extent and duration to correct the identified problem. Any activity that removes restrictions represents a move toward Free Flight.

PART II

be improved by exchange of current information about pilot intentions and airspace flow restrictions. This real-time information sharing will be available to users both on the ground and in the air, via data link. As conditions change during the planning phase or during flight, the pilot will be able to determine the actions required to safely continue to destination.

NAS-wide information sharing will allow increased collaboration between users and service providers for resolving strategic problems. For situations such as demand-capacity imbalances or adverse weather en route, this capability will support collaboration in determining when, where, and how to initiate a ground delay program or revise the route structure. Collaboration will increase the capability of users to minimize disruptions to their operations (see Figure 4-1).

Interactive flight planning will permit airlines to monitor their aircraft fleet activities during both routine and nonroutine (e.g., adverse weather) operations, allowing better use of resources as well as cost savings. Increasingly accurate data will be distributed simultaneously to service providers and all users. The data will include dynamic information, such as current and forecast weather, hazardous weather condition warnings, information on updated airport and airspace capacity constraints, and special use airspace (SUA) schedules.

Currently, most airline operations centers (AOCs) electronically auto-file flight plans directly to en route center host computers, while some air carriers file bulk-stored flight plans with each en route center. Individual flight plans are filed through the nearest flight service station (FSS).

Department of Defense (DOD) Base Operations file military flight plans through the FSS, or in some cases, military pilots file directly with FSS personnel. A significant portion of general aviation (GA) VFR pilots do not file flight plans and will not be required to do so. GA pilots, who do file flight plans, interact directly with flight service specialists to acquire preflight briefings, to file VFR or IFR flight plans, and to obtain inflight weather forecasts. GA pilots can file online rather than through the FSS by phone. Airborne pilots can file or change any segment of their flight plan by contacting air traffic control (ATC) or the FSS. Flight service specialists log flight plans into the ATC system via the host computer.

NAS modernization will expand user support and streamline the flight planning process. Today's process does not inform flight planners about existing and projected conditions in the NAS. The result is that the intended flight route may be altered by the tactical controller after departure. This increases both flight deck and controller workload. Interactive flight planning will increase user self-reliance for preflight services, but some level of flight service assistance will always be available to users (see Section 25, Flight Services).

To support improved planning capabilities, today's flight plan will be replaced by a flight profile. This profile can be as simple as the user's preferred path or as detailed as a time-based trajectory that includes the user's preferred path and preferred climb and descent profiles. The flight profile will be part of a larger data set called the flight object.

The flight object will be available throughout the duration of the flight to both users and service providers across the NAS. For an appropriately equipped aircraft operating under VFR, which has requested services from the FAA, the flight object may only contain the flight path, a discrete identification code, current location, and necessary information to initiate search and rescue.

For a flight operating under IFR, the flight object will be a much larger data set, including a preferred trajectory coordinated individually by the user and supplemental information, such as the aircraft's current weight, position, arrival and departure runway preferences, or gate assignment. Flight object information will be updated by the user and service provider throughout the flight.[4]

As the planner generates the flight profile, information on current and predicted weather conditions, traffic density, restrictions, and status of SUAs will be available to assist the planning. When the profile is filed, it will be automatically

4. The Flight object can be viewed as a discrete data file on the flight that is updated periodically and passed on by the NAS information network to service providers, as needed, to support that flight.

checked against these conditions and other constraints, such as terrain and infrastructure advisories. The operational reasons for requesting modifications or rejecting the flight profile will be

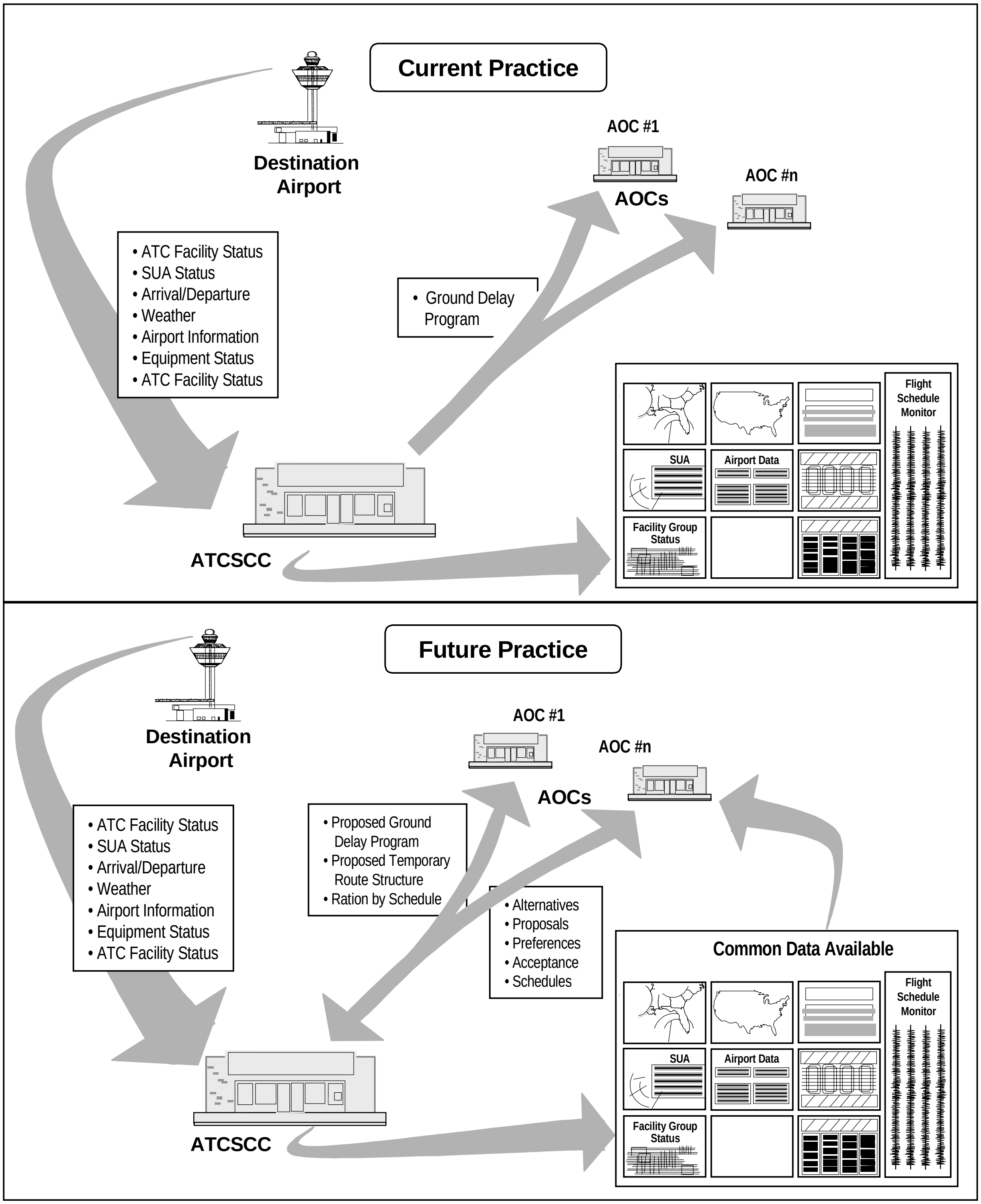


Figure 4-1. Collaboration and Information Sharing

As information sharing increases between NAS users and operators, collaboration will increase, and commercial aviation will be allowed greater control in making decisions that affect operating costs.

transmitted to the planner. After approval, the profile will be automatically distributed to service providers who will monitor the flight.

Information sharing will increase over time. Initially, data exchange between AOCs and the FAA will be the focus. As the flight object becomes more prevalent, the information available to all NAS users will be expanded to include time-based planned trajectory by flight. As information sharing and collaboration increase, NAS users will have greater influence on decisions that affect operating costs.

4.3 Airport Surface Operations

Separation of aircraft in the airport surface movement area is the responsibility of the airport traffic control tower (ATCT) (see Section 24, Tower and Airport Surface). The ATCT is also responsible for separating aircraft arriving at or departing from the airport and provides approval for vehicles to operate on airport runways. Other responsibilities include relaying IFR clearances, providing taxi instructions, and assisting airborne aircraft within the immediate vicinity of the airport (see Figure 4-2).

At today's busiest airports, surface operations often experience long delays. During low-visibility weather conditions, airport operations are dramatically slowed. Because communications are conducted via radio, frequency congestion can increase the possibility of missed instructions or confusing directions. NAS modernization will provide more efficient and safer surface operations for aircraft moving on runways and taxiways.

Users and service providers will derive significant benefits from new capabilities that improve low-visibility surface operations, taxi sequencing and

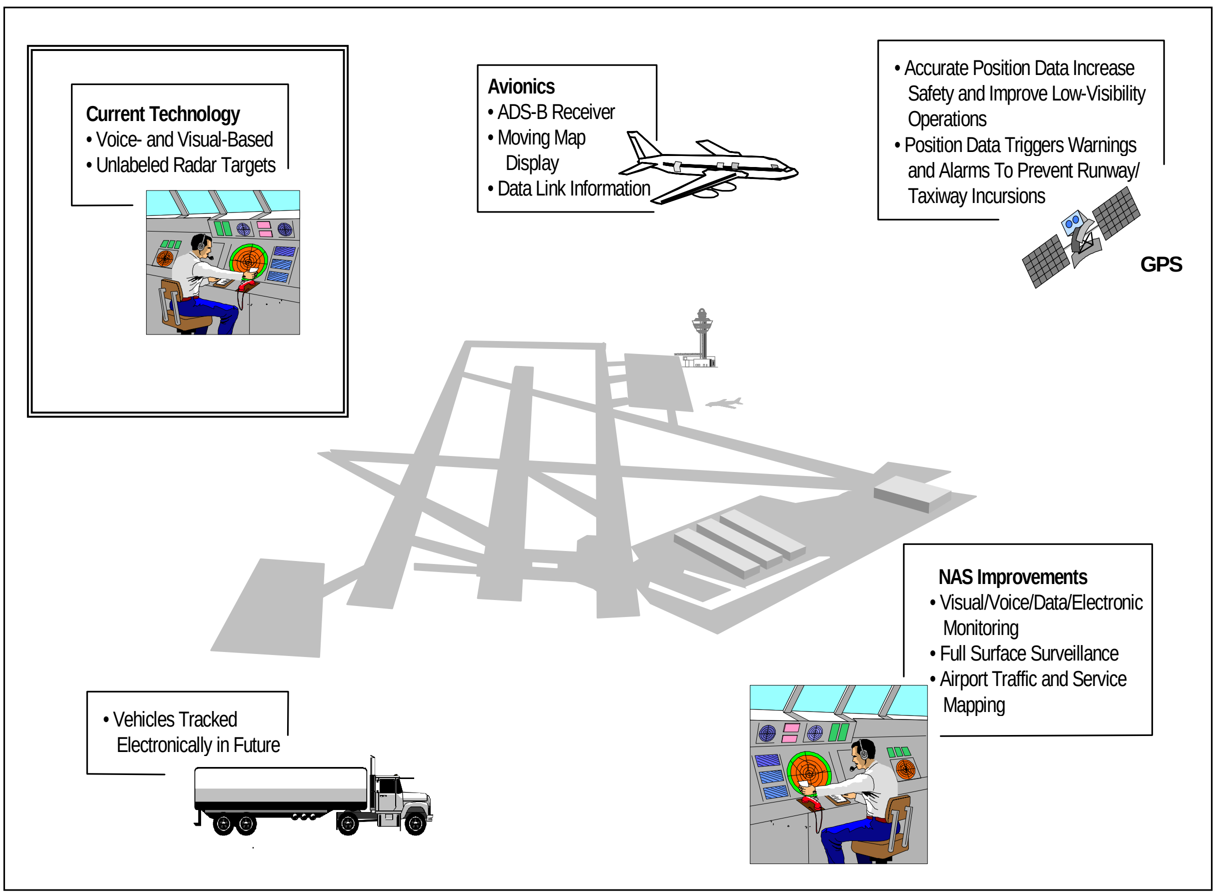


Figure 4-2. Improved Surface Operations

Improved surface operations reduce the impact of low visibility at the airport. As avionics and controller tools improve, weather-imposed delays will be minimized.

spacing, and weather and traffic situational awareness[5] in both the tower and cockpit. Faster and more reliable user/provider communications will also be realized. The use of satellite-based navigation and automatic dependent surveillance technology, updated cockpit avionics, and data link will provide the means for safer and more efficient low-visibility surface movement of aircraft and ground vehicles. These improved technologies will reduce the impact of low visibility on airport operations (see Figure 4-3).

New traffic situation displays will allow pilots, service providers, and ground vehicle operators to maintain situational awareness of all moving aircraft and vehicle traffic in their areas. This will help pilots follow taxi instructions and ground vehicle operators avoid conflicts with aircraft. Taxi operations will be possible in lower runway visual range (RVR) conditions than are possible today, reducing systemwide delays caused by weather.

Automated conflict detection and surveillance of airport movement areas, runways, and surrounding airspace will allow service providers to monitor traffic and be alerted to possible runway incursions. These capabilities will increase safety and airport capacity, and reduce taxi delays.

Surface movement decision support systems will save time and fuel by identifying the most efficient taxi sequence and routes appropriate to the departure and arrival activities. The NAS-wide information network will provide timely information about flight routes, traffic congestion, weather conditions, and destination airport operational conditions. Safety will be enhanced by reducing time between deicing operations and departures.

4.4 Terminal Area Operations

The Terminal Radar Approach Control (TRACON) provides separation and sequencing of aircraft in the terminal airspace (see Section 23, Terminal). Current TRACON operations consist mainly of standard departure and arrival routes coupled with radar vectors.[6] To improve traffic flow, departing aircraft are often vectored off the standard departure course until they can safely resume navigation along their filed route. The arrival sequence is established by vectoring aircraft and instructing them to begin descent, sometimes well before the terminal area, which results in excess fuel consumption.

NAS modernization—with augmented satellite-based navigation, automatic dependence surveillance, data link, and fully automated traffic flow management technologies—will support more flexible use of terminal airspace. Augmented satellite-based navigation will increase the number of runways available for IFR operations by providing precision approach capability to runways that lack this capability today.

Satellite-based navigation and automatic dependence surveillance will be used to establish low-altitude direct routes apart from the normal arrival and departure flows for each runway configuration used by airports. The low-altitude routes (including vertical flight) will support a segment of the user community that flies short routes between major terminal areas, providing reduced flight mileage, fuel consumption, and flight times.

Current arrival and departure procedures are based on flying fixed ground site radials (course) or distances, which are often oriented away from the destination airport. Many current arrival and departure procedures require aircraft to switch between ground navigational aids (Navaids) during critical phases of flight. Preferential arrival and departure procedures will be developed using the new capabilities inherent in satellite-based area navigation. Satellite-based navigation routes and approaches will be based on an earth geo-coordinate system that will provide accurate aircraft positions in relation to desired flight paths. This will allow aircraft to use a greater portion of the airspace around airports, increasing terminal airspace capacity.

New cockpit and ground system technologies will work together to improve traffic flow. The current practice of allowing pilots to maintain aircraft-to-

5. Situational awareness is knowledge about one's surroundings and intentions. Any improvements that can be made to increase a pilot's situational awareness will have a direct effect on increased safety and operational efficiency. Flight management systems, data link, heads-up displays, and multiple-function cockpit displays will assist in improving pilot situational awareness, providing that adequate human factors work is incorporated to prevent information overload.
6. A vector is a heading issued by controllers.

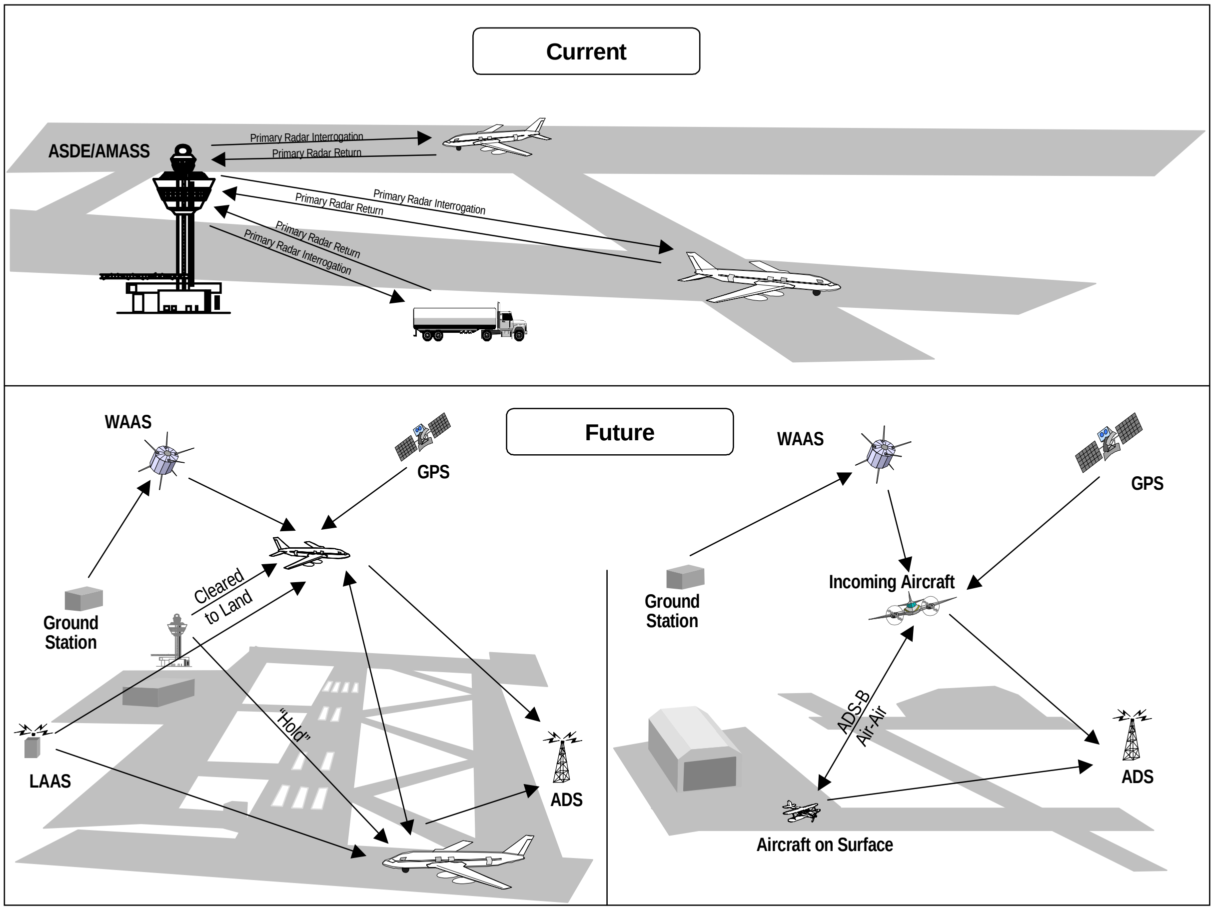


Figure 4-3. Improved Surface Movement Detection

As ADS-B equipage increases, smaller airports will benefit from better awareness of the location of aircraft and airport traffic, thereby reducing the potential for runway incursion incidents.

aircraft separation during visual weather conditions will be extended to instrument weather conditions, using cockpit display of traffic information (station-keeping), when operationally appropriate. Automated decision support tools will assist controllers in integrating departures with arrivals. Time-based metering techniques will be used to sequence and merge arrivals in accordance with users' preferences. Computerized conflict detection and resolution tools will allow service providers to monitor arrival and departure paths throughout the terminal airspace.

New terminal arrival/departure routes, based on satellite navigation, will reduce the number of vectors to airport areas. Users will receive the most expeditious route to the airport, but some radar vectoring or speed control will still be necessary to merge aircraft onto final approach. Airport capacity will be increased during instrument weather conditions by using simultaneous approaches to closely spaced parallel runways. Controllers who monitor precision approaches will be assisted by automation systems that more accurately track aircraft and calculate closure rates, vector geometries, and wake turbulence. Users will monitor adjacent traffic via cockpit display information, which will augment visual separation (see Figure 4-4).

New terminal procedures, cockpit avionics, and improved navigation and automatic dependence surveillance capabilities will enable aircraft to fly optimum climb and descent profiles. Departing aircraft will be able to fly optimum climb profiles, conserving fuel and reaching cruise altitude sooner. Arriving aircraft will remain at cruise altitude and begin descent closer to the airport. Exposure to lower-performance aircraft in low altitudes will be reduced.

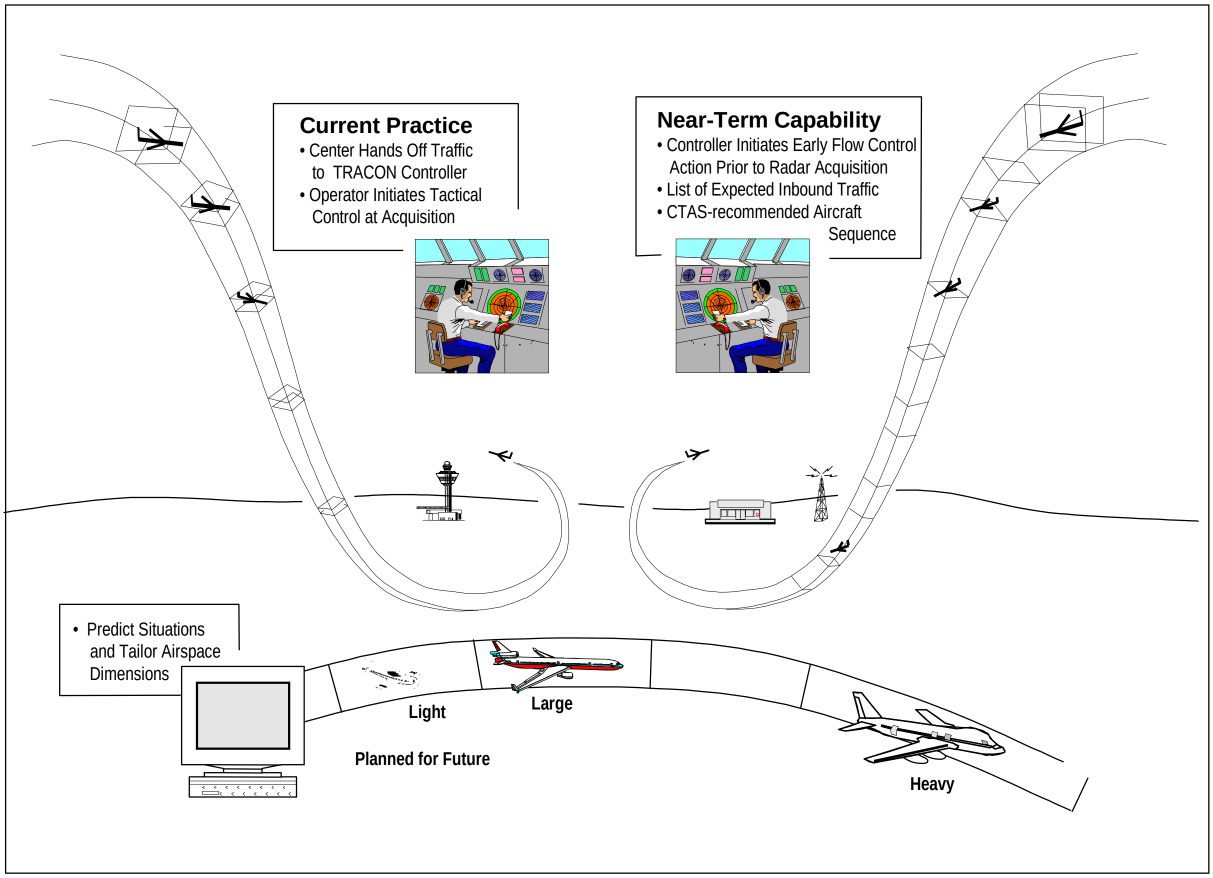


Figure 4-4. More Efficient Operations for Arrivals and Departures

Improved arrival and departure sequencing enables more planes to land or leave an airport during peak operating hours. This will alleviate the need for new runways at some airports.

Airport information, including weather reports, will be sent via data link to arriving aircraft approaching terminal areas. Data link will enable controllers and pilots to communicate using direct, addressed messages in conjunction with current voice radio communications. A direct benefit will be increased availability of voice communications channels. Data link is also expected to reduce the incidence of misinterpretation and operational degradation due to radio transmission blocking.

As satellite-based navigation augmentation is implemented, satellite precision approaches will become available throughout the NAS. This provides instrument precision approaches to many airports that currently do not have this capability. This will relieve some of the traffic congestion at major hub airports during IFR operations, easing the workload on both pilots and controllers, while allowing expanded use of other airports. The availability of additional precision approaches will provide an important safety benefit for a large segment of the aviation community and allow increased service to a greater number of airports.

4.5 En Route (Cruise) Operations

Air route traffic control centers (ARTCCs) provide en route ATC services through a ground-based network of radars, communications, and automation systems. Existing decision support tools for en route service providers are limited.

Evolving digital technologies, coupled with satellite-based navigation, automatic dependent surveillance capabilities, and cockpit avionics, will improve the way en route air traffic is managed in the future (see Section 21, En Route). Pilot situational awareness will be increased through improved cockpit avionics. The avionics will display critical flight safety information, such as weather, nearby traffic, terrain features, SUA status, notices to airmen, and significant weather advisories. Cockpit displays of real-time weather, such as heavy rain, lightning, and other thunderstorm activity, will assist pilots in avoiding hazardous conditions, thereby increasing flight safety.

Increased air traffic situational awareness of users and service providers will allow pilots to assume more responsibility for separation, routes, altitudes, and airspeed (i.e., Free Flight). The ability of air crews to dynamically select optimum routes, altitudes, and speed will be enhanced by improved communications, navigation, and automatic dependent surveillance technologies. This saves time and fuel, enabling users to make more cost-effective decisions and increasing the NAS flexibility.

Air traffic management procedures will incorporate advanced decision support tools to ensure positive separation of aircraft, while allowing maximum aircraft performance and flight path flexibility. The en route automation systems will enable a more flexible structuring of airspace and reduce current boundary restrictions. The airspace structure will be evaluated and adjusted, as necessary, to handle the demands of traffic flow or in response to weather conditions, and SUA and other NAS operational restrictions. Most en route communication and reporting will be done via data link, leading to faster and more reliable information exchange and allowing crews to more efficiently perform route and altitude planning (see Figure 4-5).

Some of the existing Navaids and airway route structures will be decommissioned consistent with the performance of satellite navigation. Routes will be retained to manage continuous high-traffic densities, terrain separation, and SUA, and to facilitate transition between airspace

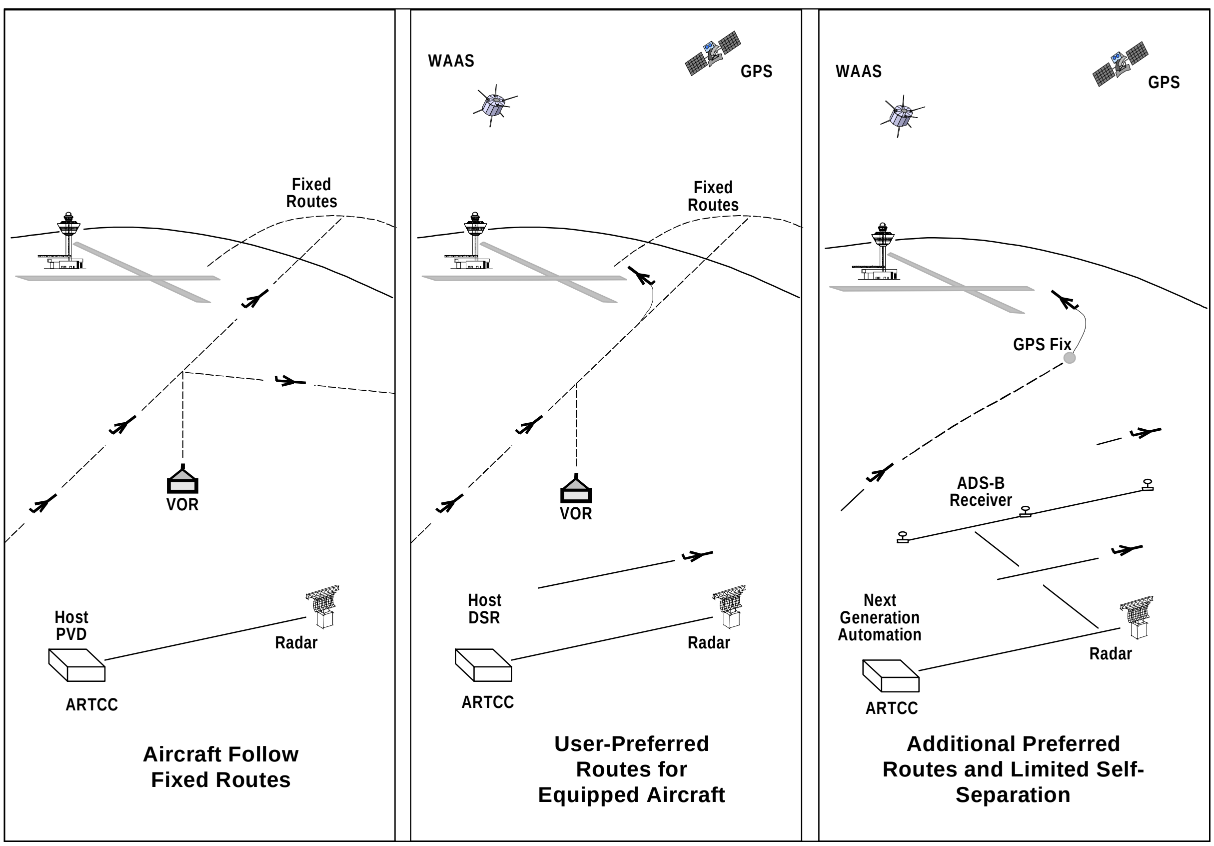


Figure 4-5. Aircraft Fly Preferred Routes

Enhancement in en route navigation and surveillance will allow users to fly preferred direct and wind-aided routes more often. This saves time and fuel, enabling users to make more cost-effective decisions and increasing the flexibility of the NAS.

with different separation standards. En route low-altitude direct routes will be implemented so that regional, business, GA, and other users whose aircraft operate most efficiently in low altitudes can benefit from Free Flight. Satellite-based navigation and procedural changes will enable lower-performance aircraft to fly desired routes at altitudes that are optimum for fuel consumption and cruise speeds.

Broadcast and processing of aircraft position and speed using automatic dependent surveillance will support air traffic services in areas not covered by ground-based radar. More accurate barometric altitude reporting will enable vertical separation above 29,000 feet to be reduced. The new capabilities, when available, will allow users to fly optimal altitudes and flight paths, thus reducing flight times and fuel consumption. A global grid of locations, defined by latitude and longitude coordinates, will augment the remaining fixed IFR routes. These grid locations will be used to define routes and transition points.

4.6 Oceanic Operations

Currently, en route and oceanic facilities are co-located in ARTCCs, but do not share communications or automation systems. In addition, oceanic controllers rely upon pilot voice position reports via high-frequency radio. The vast oceanic airspace has no ground infrastructure of Navaids or VHF radio communications. This unique operating environment has forced the en route and oceanic domains to evolve separately. As the capabilities in aircraft and on the ground improve, en route and oceanic cruise operations will become increasingly similar.

Today's oceanic operational capability is constrained by lack of surveillance, poor communications, and limited controller automation tools. Oceanic service providers use "time and distance" separation procedures based on periodic aircraft position reports relayed by a commercial service provider to oceanic ATC facilities. Some specially equipped aircraft (with the future air navigation system (FANS-1/A)) fly flexible tracks in the Central Pacific that reduce distance, separation, flight times, and fuel consumption.

Oceanic aircraft are equipped with the latest navigation avionics, such as GPS receivers and inertial navigation systems (INS), to compensate for the lack of ground-based navigation systems. In-trail climbs and descents are now available for aircraft equipped with the Traffic Alert and Collision Avoidance System (TCAS), allowing greater fuel efficiency and flexibility.

Cockpit traffic display avionics will extend pilot situational awareness. Automatic dependent surveillance broadcast (ADS-B) is expected to provide additional operational gains by allowing oceanic aircraft to laterally pass other aircraft at the same altitude by establishing an aircraft offset track. Using cockpit displays, the pilot will be responsible for maintaining minimum lateral separation from other aircraft and rejoining the original flight track (see Figure 4-6).

Oceanic operations will improve with NAS modernization (see Section 22, Oceanic and Offshore). Service providers will have a surveillance capability by means of automatic dependent surveillance addressable (ADS-A), and new automation displays. New advancements in ATC decision support tools, data link communications, surveillance, and navigation will facilitate merging domestic en route and oceanic control methods. As a result of these new capabilities, separation standards may be decreased, thereby increasing capacity.

Communications and coordination between users and service providers will be improved to a real-time capability by means of satellite communications (SATCOM) and/or high-frequency data link (HFDL). The FANS-1/A-based data link environment will evolve to one that includes ICAO/ATN-compliant communications and application services.

Any changes made to the NAS portion of oceanic airspace will be coordinated through ICAO. Coordination and information exchange between adjacent flight information regions (FIR) will be provided by interfacility data communications. Flight plans and flight progress information will be transmitted to adjacent FIRs in ICAO format.

4.7 Traffic Flow Management

Traffic flow management (TFM) optimizes airspace capacity for all phases of flight, based on demand and weather. The TFM system organizes traffic nationally and locally in order to balance

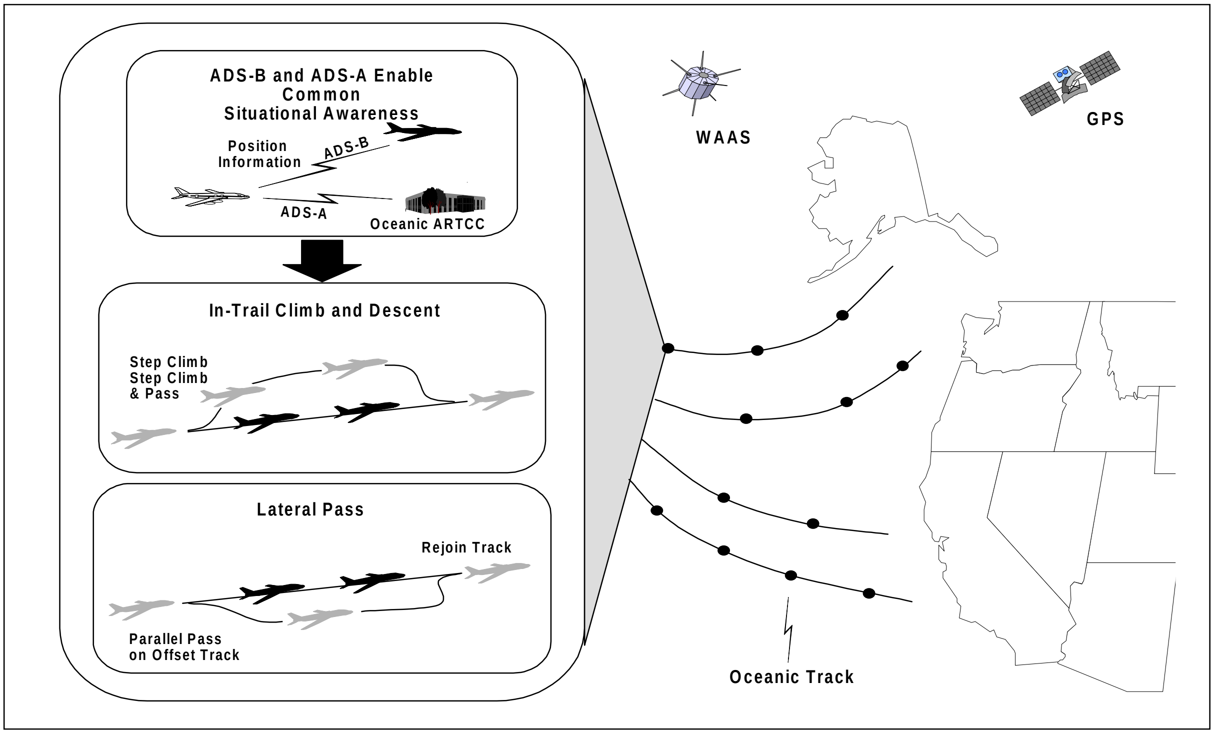


Figure 4-6. Improved Oceanic Operations

In oceanic environments, properly equipped aircraft will benefit from reduced separation standards. This will enable them to fly more wind routes and allow limited oceanic "passing" capabilities.

capacity and demand throughout the NAS (see Section 20, Traffic Flow Management). At airports, TFM determines and manages airport acceptance rates adjusted for winds, severe weather, runway configuration, operational factors, and equipment outage.

In the future, TFM, in collaboration with users, will employ both ground delays and airborne flight metering to manage traffic to meet the airport/sector acceptance rate. Instead of being assigned arrival slots at specific times for each flight, each user will be allocated a set number of arrivals within a specified time frame. Users will schedule departures to meet the designated arrival times.

TFM will monitor all SUA to identify availability of airspace for general use. Allocating inactive SUA to civilian users will optimize use of this shared resource. This requires strategic and tactical airspace management based on planned and actual movements of aircraft in real time.

To improve strategic planning, new tools will enable the FAA and users to evaluate operational activities at the end of each day. The tools will simulate the impacts of various decisions. In this manner, more efficient "game plans" between the FAA and the users will be developed. These strategic plans can then be implemented by NAS users and service providers to ensure that operations proceed smoothly and delays are minimized.

4.8 Managing the NAS Infrastructure

Many internal agency functions support the array of new technologies and operations that characterize the modernized NAS (see Section 27, Infrastructure Management). In the maintenance area, infrastructure maintenance activities will be monitored on a day-to-day basis. This service will be based on a national perspective rather than individual elements of the NAS infrastructure. It will increase the use of remote monitoring and control and facilitate collaboration between service providers and users, allowing users to participate in prioritizing scheduled and unscheduled repairs to essential NAS equipment.

4.9 Summary

NAS modernization emphasizes user benefits, technology insertion, and new procedures. The flight-specific and generalized operational descriptions are drawn from the anticipated flight operations, which range from clearance delivery to arrival at the destination airport using NAS enhancements derived from the modernization plans.

The essential focus is the Free Flight vision of a future NAS that permits users to fly without the constraints of today's structured routes and airspace. Air traffic restrictions are imposed to ensure separation, preclude exceeding airport capacity, prevent unauthorized flight through SUA, and ensure flight safety. This shift will be made possible by decision support tools for controllers, an enhanced pilot role in separation assurance using advanced cockpit avionics, use of space-based navigation aids, and use of a dynamic collaborative decisionmaking process. NAS modernization represents an approach that takes advantage of technology used in conjunction with new requirements and standards. NAS modernization will help the FAA operate more efficiently and enable the agency to be more responsive to user requests while maintaining the highest level of safety.

The current CONOPS is not an end state and it will be adjusted in collaboration with the user community as the NAS is modernized. The CONOPS will accommodate changes that will likely result from lessons learned from implementing new capabilities and potential benefits of new technology.

5 EVOLUTION OF NAS CAPABILITIES

5.1 Introduction

In each major operating area or domain of the NAS, new technologies and accompanying procedures and training will provide new capabilities to NAS users and service providers. This section presents an overview of these capabilities and presents illustrations that, taken together, provide snapshots of NAS modernization over the course of this architecture (1998–2015). A more detailed discussion and illustrations also appear in Appendix D. Figure 5-1 contains a chart of the modernization phases and the capabilities that will be implemented in each phase.

The schedule developed for delivery of the capabilities in the NAS architecture is constrained by the ability to transition to new technology in NAS operations and availability of funding. The resulting capability lists divide the implementation into three phases. Phase 1 covers 1998 through 2002, Phase 2 covers 2003 through 2007, and Phase 3 covers 2008 through 2015.

5.1.1 Phase 1 (1998–2002)

During Phase 1, current systems and services will be maintained while advanced services and upgraded systems are introduced. New technologies—such as the Global Positioning System and Wide Area Augmentation System (GPS/WAAS), User Request Evaluation Tool core capabilities limited deployment (URET CCLD), automatic dependent surveillance broadcast (ADS-B), and Center Terminal Radar Control Approach Control Automation System (CTAS) (consisting of the passive Final Approach Spacing Tool (pFAST) and traffic management advisor single center (TMA SC))—will be integrated through a logical series of changes.

Controller-pilot data link communications (CPDLC) implementation will begin a phased approach to develop en route aeronautical telecommunications network (ATN)-compliant data link services. CPDLC Build 1 and 1A will use very high frequency digital link (VDL)-2 for the air-ground subnetwork and will provide data link coverage to aircraft at 10,000 feet and above. However, voice communication will remain the primary method of information exchange during this period.

The principal goal of traffic flow management (TFM) is to increase airspace and airport capacity through strategic planning, tracking, and efficient tactical control of aircraft. TFM will focus on building collaborative decisionmaking support services that will allow the FAA to interact with airlines in real-time to resolve traffic congestion. Collaborative decisionmaking capabilities will be enhanced by ration-by-schedule and control-by-time-of-arrival capabilities, which will augment current ground delay procedures. Additionally, airline operations center (AOC) automation will be directly linked to FAA TFM to support real-time decisionmaking between airlines and the FAA.

The following activities will be included in Phase 1:

- Complete commissioning of airport surface detection equipment (ASDE) with the Airport Movement Area Safety System (AMASS)
- Implement the Traffic Information Service (TIS) on Mode-S to provide data link traffic information to pilots
- Deploy weather on display system replacement (DSR) to enable integration of next-generation weather radar (NEXRAD) weather information into en route controller displays
- Deploy ITWS stand-alone to selected airports
- Initiate use of flight information service (FIS) to the cockpit
- Implement multisector oceanic data link (ODL) at Oakland and New York facilities
- Upgrade the en route, oceanic, and the TFM systems
- Begin deploying the Standard Terminal Automation Replacement System (STARS) and DSR
- Begin deployment of Free Flight Phase 1 Core Capabilities Limited Deployment (FFP1 CCLD), including collaborative decisionmaking (CDM), initial surface movement advisor (SMA), URET CCLD, TMA SC, and pFAST

PART II

Phase 1	Phase 2	Phase 3
Continue NAS Modernization and implement limited Free Flight prototypes.	**Continue NAS modernization and begin transition to Free Flight.**	**Achieve Free Flight operations.**
Complete ATC DSS infrastructure sustainment and begin "opening" systems such as Host, STARS, and TFM. Collaboration between AOC's and ATCSCC is underway. Begin Installing new infrastructure to support more precise position reporting and less structured routes. FFP1 CCLD is deployed and procedural changes are made to enhance operations.	New "open" DSS system are installed, and new CNS infrastructure is being deployed. Free Flight concepts are implemented as procedural changes are made to take advantage of more collaboration with users.	New integrated ATC and TFM DSS tools allow greater sharing of 4-D flight profiles throughout the NAS, enabling greater flexibility and planning with users. Capacity is increased as more accurate position reports are incorporated onto DAA tools. Installation of CNS is completed.
Key Technologies •CPDLC •WAAS/GPS •URET CCLD •ADS-B Air-to-Air •pFAST •STARS	Key Technologies •Limited NEXCOM •WAAS/LAAS •ADS-B Ground Stations •ITWS •STARS P^{3}I •CP	Key Technologies •Full NEXCOM •Full CP •Next-Generation En Route Automation •aFAST/WV •NAS Info System
1998–2002	**2003–2007**	**2008–2015**

1998–2002			2003–2007			2008–2015		
Initial WAAS Cruise	URET CCLD (FFP1)	ITWS Stand-alone	LAAS Cat I	Conflict Probe	ADS-B Gap-Filler	Integrated Tower Area Surveillance	CPDLC Build 3 via VDL-Mode-3	NAS-Wide Data Link
ASDE with AMASS	Single Center Metering (FFP1)	Terminal Weather Exchange	LAAS Cat II/III	Improved En Route Surveillance (ASTERIX/SI)	Integrated En Route Surveillance with ADS-B	CPDLC Build 2 via VDL-Mode-3	NAS-Wide Information Sharing	Conflict Resolution with Multicenter Metering
Air-Air ADS-B	pFAST (FFP1)	Enhanced MDCRS	Oceanic surveillance ADS-A	Improved Weather on STARS	Integrated Terminal Surveillance w/ ADS-B	aFAST with Wake Vortex	Enhanced SMS	Interactive Airborne Refile
Initial WAAS Precision Approach	Multi-Sector Oceanic Data Link		Oceanic 50/50 nmi Lateral/Longitudinal Separation	Enhanced En Route Coverage	Multicenter Metering with Descent Advisor	Improved CDM for Maintenance Activities	ELT for SAR and Flight Following	Full CDM
			SMA					
	Initial FIS	Expanded TWIP	Improved Terminal Surveillance (ASTERIX/SI)	Flight Plan Evaluation	SMS			Automatic Simultaneous Hazardous Weather Notification
Initial SMA (FFP1)	CPDLC Build-1	Low Altitude Direct Routes - Using WAAS	Runway Incursion Reduction	Expanded TDLS Service	Low-Altitude Direct Routes - Expanded Radar Coverage			
Initial CDM (FFP1)		Terrain Avoidance	CDM for Maintenance Activity	CPDLC Build 2 via VDL-Mode-2	Low-Altitude Direct Routes - Expanded Surveillance Coverage			
Weather on DSR		CPDLC Build-1A						

Figure 5-1. Modernization Phases

- Begin initial collaborative decisionmaking between AOC and the air traffic control system command center (ATCSCC)
- Deploy initial WAAS navigation system
- Initiate use of ADS-B air-air for improved cockpit situational awareness
- Begin deployment of CPDLC Build 1 and Build 1A with ATN-compliant air traffic control (ATC) data link services (e.g., CPDLC) in en route airspace using VDL-2 for the air-ground subnetwork.

5.1.2 Phase 2 (2003–2007)

Phase 2 automation enhancements include upgrading and expanding CTAS, STARS preplanned product improvements (P^3I) development, and en route automation upgrades. STARS P^3I includes the capability to improve arrival traffic sequencing using time-based separation techniques.

Free Flight concepts will be implemented with procedural changes to take advantage of increased collaboration capabilities with users. CPDLC services will include Build 2 that provides International Civil Aviation Organization (ICAO)/ATN-compliant services using VDL-2 air-ground network. Build 2 will bring the Future Air Navigation System (FANS) and domestic CPDLC message sets closer together in format and capability.

The following activities will be included in Phase 2:

- Implement flight plan evaluation to increase collaboration with users
- Deploy surface management system (SMS) service provider tools to improve surface traffic movement operations
- Deploy runway incursion reduction at selected airports
- Implement improved weather data on STARS
- Transition to digital radios for voice in high-altitude en route sectors
- Provide 50/50 separation services to oceanic aircraft
- Deploy CTAS TMA multicenter (MC) and complete pFAST deployment
- Deploy conflict probe (CP) nationally
- Implement a new communication, navigation, and surveillance (CNS) infrastructure featuring the GPS, WAAS, and Local Area Augmentation System (LAAS), providing virtually universal navigational coverage and instrument approaches
- Begin implementing CPDLC Build 2 providing ICAO-ATN compliant services using VDL-2 air/ground network to provide data link services between users and en route facilities
- Accommodate both FANS-1/A- and ATN-equipped aircraft in oceanic airspace.[1]
- Begin using oceanic data link and automatic dependent surveillance (ADS) to reduce separation between suitably equipped aircraft flying oceanic routes
- Begin use of GPS/ADS-B data for surveillance service in nonradar and radar areas
- Implement Free Flight capabilities as procedural changes are developed.

5.1.3 Phase 3 (2008–2015)

Phase 3 automation upgrades will fully integrate all technologies into air traffic management. This phase will introduce the enhanced en route/oceanic system and full implementation of digital communications and air traffic planning tools that incorporate weather prediction and advisories. The oceanic and en route domains will employ similar procedures and separation methods.

Users will have the flexibility to file new, NAS-wide 4-dimensional flight profiles. This allows the user to meet any flight objective while providing maximum strategic planning for service providers. As the phase-in of new technology reaches completion, obsolete navigation systems will be phased down. Increased capabilities of the modernized NAS will eventually allow increased capacity utilization through VFR-like flight operations in IFR conditions.

1. Note that service-provider-operated communications services may be retained for data link that supports oceanic ATC operations and potentially as a backup capability in domestic airspace.

Maximum runway utilization rates, aircraft performance characteristics, and departure traffic schedules are balanced to produce a constant and efficient flow of arriving traffic to the runway. DSS tools will assist in determining the most advantageous descent point from cruise altitude, so each aircraft can fly the optimum descent profile for fuel efficiency. Airport, weather, TFM, and ATC system performance data will be available to aircraft via service provider data link.

The following activities will be included in Phase 3:

- Provide NAS-wide information sharing
- Provide interactive airborne refile to enable increased collaboration with users
- Provide integrated tower area surveillance for tower and surface
- Deploy enhanced SMS to fully integrate operations between surface and arrival/departure operations
- Deploy aFAST with wake vortex at TRACONs
- Provide conflict resolution with multicenter metering to evaluate requested flight path amendments across center boundaries
- Deploy NAS-wide data link via full next-generation air-ground communication system (NEXCOM) and CPDLC Build 3 via VDL-Mode-3 at all high-altitude en route and high-density terminal and tower facilities
- Begin using 4-dimensional (longitudinal, lateral, vertical, time) flight profiles to enable greater flexibility and planning with users and providers
- Employ full use of digital communications for voice and data in the en route environment
- Provide common en route and oceanic services
- Conduct visual flight rules (VFR)-like operations under IFR conditions.

5.2 Capabilities Overview

5.2.1 Background

In 1997, a concept of operations for a new NAS air traffic control system was generated. Two documents were developed: the *Government/Industry Operational Concept for the Evolution of Free Flight* was developed by the FAA and aviation community through the RTCA. The RCTA concept provides a joint view of how service provider and user interact in the new NAS. The FAA's concept is consistent with this document. *A Concept of Operations for the National Airspace System in 2005*, generated by FAA Air Traffic Services and approved September 30, 1997, presents the operational concept for the NAS from the perspective of the service providers, including detailing how they interact with air traffic. Together these make up the NAS concept of operations for the future, commonly referred to as the CONOPS.

The CONOPS does not address all aspects of the NAS. It assumes that many current capabilities will remain in place and address only those services and capabilities that need to be changed.

The NAS architecture is derived from the requirements of the CONOPS, and the NAS modernization architectural diagrams show the functional decomposition of the NAS. These diagrams are the basis for more detailed engineering diagrams that describe the implementation of capabilities in terms of specific functions and systems, their interdependencies and interfaces.

5.2.2 Assumptions

The following assumptions were made to define the scope of the capabilities.

First, the capabilities addressed are derived from the CONOPS, which focuses on changing capabilities and assumes that existing capabilities not addressed will remain as they are today.

Second, functions are assigned to phases and addressed. It is not assumed that all sites, or even all geographic areas, of the NAS will have the capabilities by that time phase. The precise number of sites or geographic areas where the improvements will be in place has not been established. In some cases, single installations and prototype systems are included to better show the progress of the NAS modernization.

Third, aircraft equipage (i.e., data link, satellite navigation equipment, etc.) is not to be mandated. Traditional voice radios and ground-based navigation aids will be available far into the future. However, benefits from NAS modernization will be made available to aircraft commensurate with the avionics equipage of the aircraft.

Fourth, for the purposes of illustration, most capabilities have been depicted in five phases of flight. They are:

- *Flight Advisory/Preflight*: Includes flight planning and preflight and postflight coordination activities
- *Tower/Airport Surface*: Includes takeoff, landing, gate activities, and taxi and ramp operations
- *Departure/Arrival*: Includes climb-out, descent, approach, and other terminal operations
- *En Route/Cruise*: Includes all operations between and above terminal areas
- *Oceanic*: Includes oceanic and offshore operations.

5.2.3 Sample Illustration of NAS Capability Diagram

Top-level diagrams showing the major components and the data flows between these components are available for each capability identified in the NAS Modernization Capabilities matrix (see Figures 5-2 through 5-4). These diagrams illustrate the changes anticipated in the NAS during the modernization phases as well as various phases of flight on a capability-by-capability basis. Short textual descriptions follow each diagram to provide a clearer picture of what takes place during that phase.

The differences in the capability "Increased Navigation/Landing Position Accuracy and Site Availability" for two modernization phases for Arrival/Departure are shown in Figures 5-2 and 5-3. Figures 5-2 and 5-4 illustrate the differences in Phase 1 between en route/cruise operations and arrival/departure operations.

A complete set of diagrams addressing the changes in the NAS capabilities throughout NAS modernization is included in Appendix D. The systems engineering of all NAS capabilities is an ongoing process and the diagrams will be updated periodically.

These updates will be posted to the FAA Web site (http//www.faa.gov) as they become available.

PART II

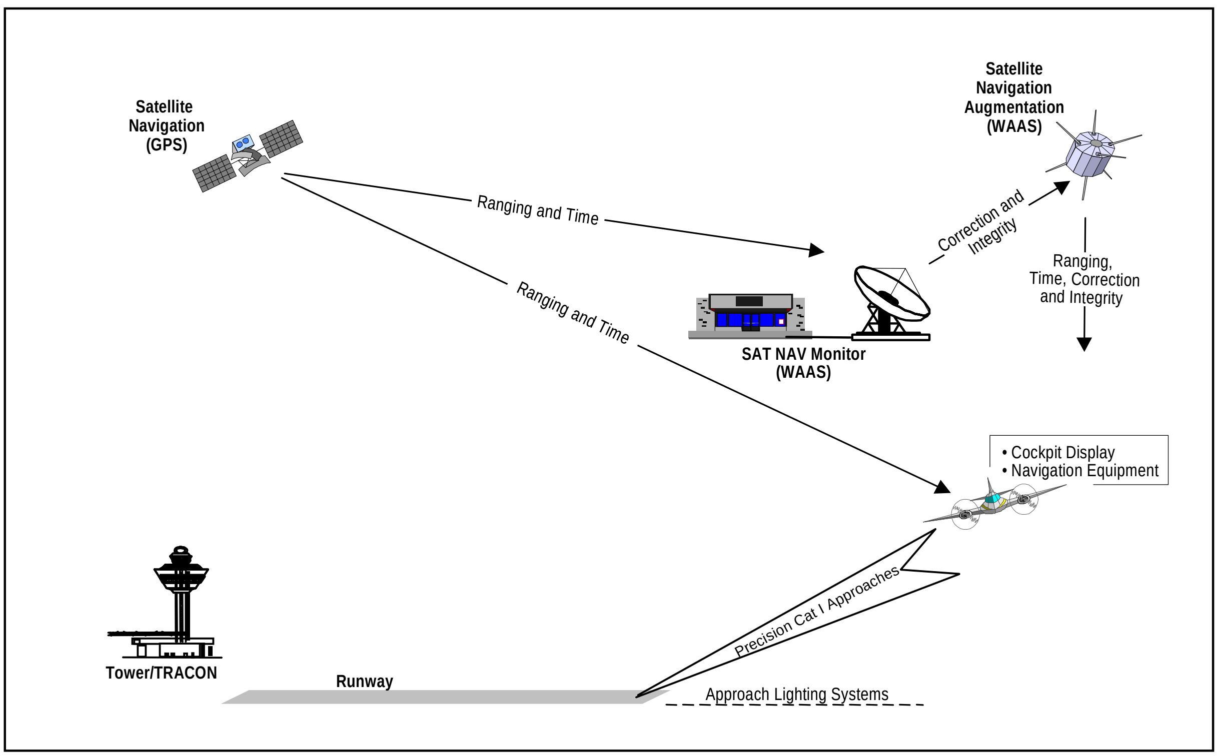


Figure 5-2. Increased Navigation/Landing Position Accuracy and Site Availability, Air Traffic Services Arrival/Departure, Phase 1 (1998–2002)

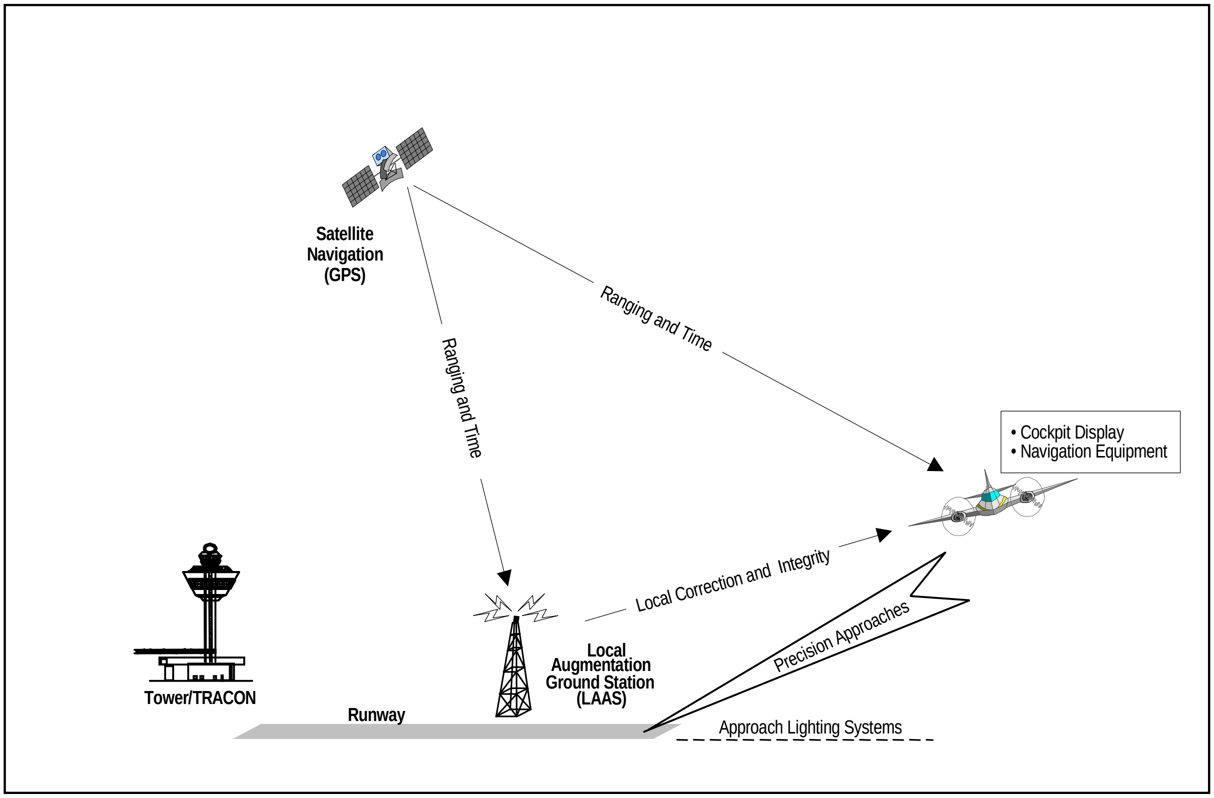


Figure 5-3. Increased Navigation/Landing Position Accuracy and Site Availability, Air Traffic Services Arrival/Departure, Phase 2 (2003–2007)

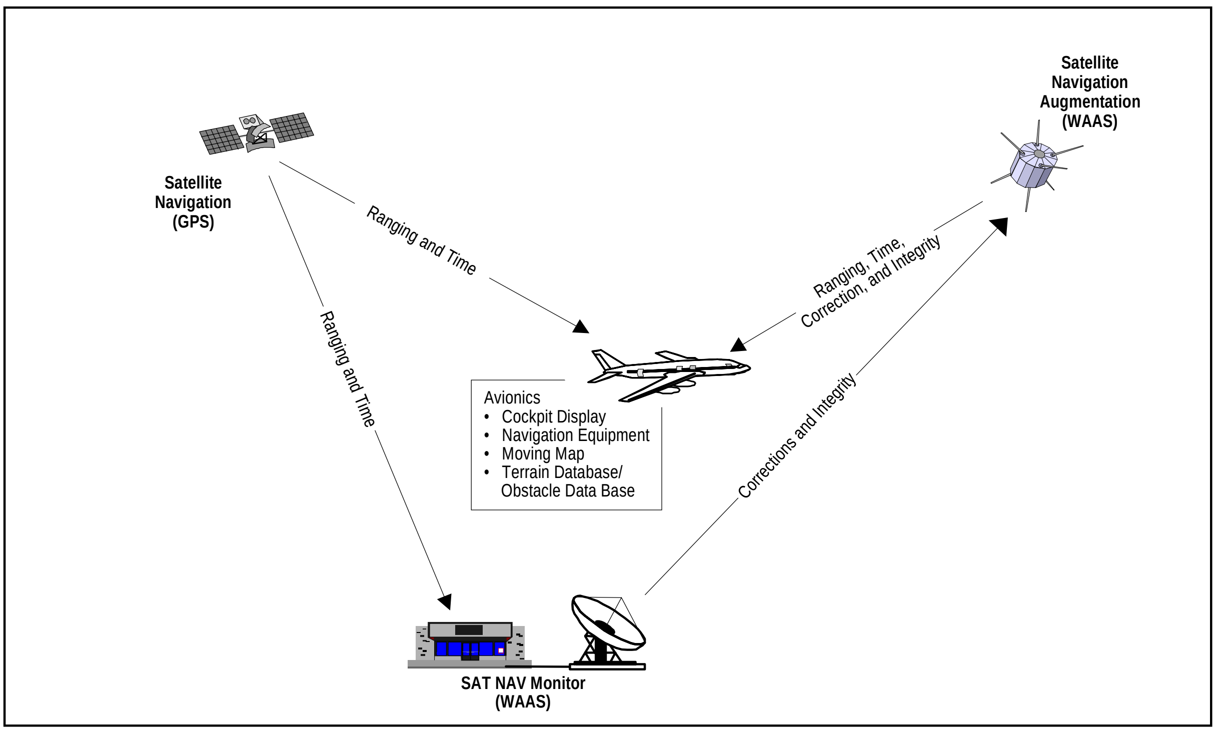


Figure 5-4. Increased Navigation/Landing Position Accuracy and Site Availability, Air Traffic Services En Route/Cruise, Phase 1 (1998–2002)

Appendix D also contains a capability matrix, which addresses air traffic service capabilities throughout the active phase of flights and NAS management services that cross domains of flight or involve infrastructure management issues.

5.3 Summary

Viewing NAS modernization in terms of the capabilities provides insight into the complex integration that must be accomplished to advance the NAS towards Free Flight. New systems by themselves do not provide new services. Capabilities emerge only when combined with training, procedures, and certification/regulation, where applicable.

In the next section, risk management is examined. Many NAS modernization concepts have never been proven in operational use. Strategies to mitigate the risks of trying new technologies and procedures are discussed.

6 FREE FLIGHT PHASE 1, SAFE FLIGHT 21, AND CAPSTONE

The main objective of NAS modernization is to move the NAS toward a new type of flight operations known as Free Flight. Free Flight will allow pilots to change routes, speeds, or altitudes, as needed, while in en route and oceanic air space. Air traffic controllers will not impose restrictions on pilot-initiated changes, except when there is potential conflict with other aircraft or special use airspace (SUA). This capability will allow pilots to fly optimized profiles, the most efficient cruise speeds, wind-aided routes, and arrival descent profiles. Any activity that removes operational restrictions is a move toward Free Flight.

Free Flight Phase 1 Core Capabilities Limited Deployment (FFP1 CCLD) incorporates guidance provided by the NAS Modernization Task Force. FFP1 CCLD is intended to provide early user benefits and mitigate technical risk by implementing key automation capabilities at specific sites within the NAS, for evaluation by aviation stakeholders and FAA operators. The deployments will allow computer-human interface (CHI), training, and safety factors to be evaluated. After the FAA and the users have gained experience and evaluated the individual FFP1 CCLD capabilities, decisions will be made on whether to deploy them to additional locations.

Safe Flight 21 will effect integration of new technologies, systems, procedures, and training for pilots and controllers. Safe Flight 21 deploys and evaluates certain air traffic control systems and avionics that use new communications, navigation, and surveillance technologies in an operational environment. These new technologies include applications such as automated dependent surveillance broadcast (ADS-B) for air-air and air-ground surveillance, and flight information services via data link. Avionics, certification, and procedural development are cost and schedule risks that must be mitigated. Additionally, user benefits must be proven before avionics and associated ground equipment capital investments can be made.

The Alaska Capstone program will evaluate safety and efficiency improvements identified by the National Transportation Safety Board (NTSB). The project will focus on the aviation services, flight rules, and weather observations available to pilots operating in an aviation-dependent portion of western Alaska.

The following paragraphs describe the FFP1 CCLD, Safe Flight 21, and Capstone programs. These programs identify and resolve risks associated with the development and deployment of new operational tools and procedures, as well as those associated with training, human factors, and user acceptance. Additional details regarding the system and interface dependencies, on which these capabilities depend, can be found in the functional and domain sections of this document (Part III, NAS Architecture Description).

PART II

6.1 Free Flight Phase 1 Core Capabilities Limited Deployment Description

FFP1 CCLD will consist of limited deployment of controller automation decision support tools, communications, and traffic flow planning tools, which are a part of Air Traffic Management (ATM) capability. FFP1 CCLD will be deployed at selected air traffic control (ATC) facilities to obtain and evaluate early benefits to service providers and NAS users, leveraging proven technologies with procedural enhancements. FFP1 CCLD will employ an evolutionary approach to system development and deployment that maintains a high level of NAS safety. FFP1 CCLD capabilities will be deployed in phases rather than as fully mature capabilities. FFP1 CCLD is a part of NAS modernization activities and will require infrastructure support from the Host replacement, the display system replacement (DSR), and the Standard Terminal Automation Replacement System (STARS), as well as other systems and programs. FFP1 CCLD components are:

- Conflict probe (CP), as represented by the User Request Evaluation Tool core capabilities limited deployment (URET CCLD)
- Center TRACON Automation System (CTAS) Traffic Management Advisor Single Center (TMA SC)
- Passive Final Approach Spacing Tool (pFAST)
- Collaborative decisionmaking (CDM) with airline operations centers (AOCs)
- Initial Surface Movement Advisor (SMA).

Conflict Probe (URET CCLD). This capability will be added at the DSR D-side (nonradar controller) position. URET CCLD's planning capability allows the D-side controller to manage en route user requests by identifying potential air traffic conflicts. It systematically checks for conflicts between aircraft (20-minute look-ahead) and between aircraft and SUA (40-minute look-ahead). If a conflict is detected, URET CCLD will provide the D-side controller with a visual indication of the problem. Updated SUA status will be available, and URET CCLD will automatically check flight trajectories against those data to determine if an airspace conflict exists.

CTAS TMA SC. This tool will calculate meter fix crossing times for all inbound aircraft to destination runways within air route traffic control center (ARTCC) airspace. CTAS TMA SC capability will operate on the radar controller's display and in the traffic management unit. It will provide controllers with the capability to develop arrival sequence plans for selected airports and will assign aircraft to runways to optimize airport capacity. The CTAS TMA traffic management tool computes an aircraft's estimated time of arrival. It assigns a scheduled time of arrival, outer meter arcs, meter fixes, and final approach fixes for each aircraft to meet the flow constraints established by traffic management coordinators. The meter list is available to the terminal radar approach control (TRACON) facility for monitoring the final approach fix and runway threshold sequencing when the aircraft is in TRACON airspace.

CTAS pFAST. This tool adds a new capability that assists controllers to optimally merge and sequence aircraft and assign runways according to user preferences and system constraints. It maximizes runway acceptance rates and meets user needs for operational efficiency in congested terminal airspace areas. pFAST uses flight data, track information, and controller inputs to generate a set of trajectories that form the basis for computed runway assignments. The trajectories also incorporate current weather conditions and aircraft flight characteristics. The scheduled time of arrival to the assigned runway final approach fix and runway threshold is then assigned. The pFAST display will enhance controller situational awareness, especially during heavy traffic operations.

CDM. Development and deployment of this capability will focus on building automation tools that will allow the FAA and the airlines to coordinate system resources in real time in response to airspace conditions. The three tools, Enhanced Ground Delay Program, NAS Status Information, and Collaborative Routing, will provide users and service providers with timely access to information. This information sharing will be the foundation of all collaborative efforts in NAS modernization. It will provide a common view of all NAS data and promote a cooperative effort to manage NAS traffic. Traffic flow managers' decisionmaking will improve because of the availability of better NAS user intent data, while NAS user decisionmaking will improve because of more timely and complete information on NAS operational status.

Initial SMA. This tool provides a one-way feed of arriving traffic information from the approach control automation system to ramp control computers for airline personnel use. Ramp controllers will use this information to plan and manage aircraft movement to/from gates and on ramp areas. This will improve gate operations and ground support services, resulting in a reduction of taxi times and takeoff delays.

The goal of FFP1 CCLD is to evaluate these automated decision support capabilities by the end of 2002 and begin national deployment during NAS Modernization Phase 2. FFP1 CCLD will not be a full-scale test of NAS modernization, but rather a limited test of decision support automation systems. The FFP1 CCLD program will be designed to derive early benefits from automation system upgrades as part of the larger NAS modernization program.

6.2 Safe Flight 21

The Safe Flight 21 project has replaced the Flight 2000 program. This government/industry initiative is designed to demonstrate and validate, in a real-world operational environment, the capabilities of advanced communication, navigation, and surveillance technologies, associated air traffic systems, and the pilot/controller procedures. Following are Safe Flight 21 capabilities and procedures, which constitute the means to move toward Free Flight.

- *Flight Information Services (FIS) for Presenting SUA Status, Weather, Windshear, Notices to Airmen (NOTAMs), and Pilot Reports (PIREPs) to Pilots.* Enhanced graphical and tabular information will be electronically transmitted to the cockpit. Data will be used to improve the content and timeliness of relevant flight planning information.
- *Controlled Flight Into Terrain (CFIT) Avoidance Through Graphical Position Display.* This will provide cost-effective terrain data in the cockpit to all airspace users for improved situational awareness.
- *Improved Terminal Operations in Low-Visibility Conditions.* This will provide improved situational awareness in the cockpit by using ADS-B position information of nearby aircraft. Data will be presented on a cockpit display of traffic information (CDTI) to enable the pilot to judge distance and speed of preceding aircraft in marginal weather conditions. This will yield benefits from increased arrival rates and access to airports.
- *Enhanced See and Avoid.* Integration of several communications, navigation, and surveillance (CNS) capabilities will be demonstrated to electronically provide improved traffic information to the pilot. Three ADS-B links with CDTI (1090 MHz, UAT, and very high frequency digital link (VDL) Mode-4) will be evaluated to determine which works best and is most compatible with the NAS infrastructure.
- *Enhance Operations for En Route Air-Air.* Use of ADS-B, CDTI, data link, and related technologies will be evaluated to examine the potential for delegating separation authority to the cockpit.
- *Improved Surface Navigation.* The capability of ADS-B, CDTI, and data link to improve the ability of the pilot to navigate on the airport surface in all weather conditions will be evaluated.
- *Enhanced Airport Surveillance for the Controller.* The enhanced information provided the pilot would also be provided to the controller through a digital data link. This information can be integrated with the radar data at airports equipped with ASDE surface radar.
- *ADS-B Surveillance in Nonradar Airspace.* Use of ADS-B will be examined in areas outside of radar coverage to allow controllers to provide separation services rather than procedural separation. Benefits expected would be increased safety, access to airspace, and route flexibility.
- *Establish ADS-B Separation Standards.* Integration and fusion of surveillance data from ADS-B and normal radar data will be tested for the possibility of reducing separation standards.

The Safe Flight 21 activity venues will include the Ohio Valley—with the Cargo Airline Association (CAA)—and in Alaska. The Safe Flight 21 project will focus primarily on developing a suitable avionics technology, pilot procedures for air-air surveillance, and developing a compatible ground-based automatic dependent surveillance system for ATC. The Ohio Valley venue of Safe Flight 21 will test three candidate avionics/data link technologies for air-air surveillance. They are the universal access transceiver (UAT), the self-organizing time division multiple access (STDMA) radio (also known as VHF data link-Mode-4, or VDL-4), and the Mode-S (1090 MHz) squitter.

The Ohio Valley venue will help test avionics, which periodically broadcasts the aircraft position (i.e., ADS-B), derived from the Global Positioning System/Wide Area Augmentation System (GPS/WAAS). These tests will occur in the terminal areas, which support cargo aircraft operations at Memphis, Wilmington, Louisville, Scott AFB, and Nashville. ADS-B-equipped aircraft will be able to receive the broadcast and display the position of other ADS-B-equipped aircraft CDTI. Pilots will use the CDTI display to:

- Identify and follow aircraft in the arrival pattern, thus maintaining higher arrival rates during reduced visibility conditions in the terminal area
- Provide situational awareness of the position of nearby aircraft.

The Ohio Valley project will also use GPS Local Area Augmentation (LAAS) avionics and the CDTI display with a moving map feature to help pilots taxi on the airport surface during reduced visibility conditions. GPS LAAS avionics will provide the precise navigation position required for arrival and surface operations. Vehicles that operate on the airport movement area will also be equipped with comparable equipment.

Finally, the Alaska portion of the Safe Flight 21 project will integrate ADS data and radar data to determine if aircraft separation standards can be reduced. Except for testing use of air-air surveillance to maintain higher arrival rates during reduced visibility conditions in the terminal area, the Safe Flight 21 program will test all of the above concepts in Alaska.

As we evolve toward Free Flight, Safe Flight 21 will help accelerate implementation of NAS technologies and approval of procedures needed to achieve full operational efficiency and safety benefits. This early demonstration and validation of operational enhancements will also serve to reduce the near-term risk of implementing new technologies and the long-term risk and cost of transitioning to the remainder of the NAS. Certification activities associated with Safe Flight 21 will ensure that Free Flight technologies and procedures will meet FAA safety requirements while providing benefit.

6.3 Capstone

The FAA Alaskan Region's Capstone Program of infrastructure modernization provides and validates safety and efficiency improvements recommended in the NTSB Safety Study (NTSB/SS95/05), *Aviation Safety in Alaska.* Capstone focuses on safety by improving infrastructure in Bethel and the surrounding area, a small portion of western Alaska. It will address the operating environment and aviation infrastructure, weather observations and recording, airport condition reporting and adequacy of the current instrument flight rules system. A coalition of Congress, FAA, and the Alaskan Aviation Industry Council supports Capstone as an essential safety enhancement to this aviation-dependent environment. Additionally, these Alaskan modernization efforts will precede and can complement the data collection and risk-reduction efforts of the Safe Flight 21 program. This will occur in three areas: avoidance of controlled flight into terrain, procedural development for enhanced see-and-avoid, and flight information services product development.

6.4 Risk Mitigation

The FAA's Acquisition Management System requires risk management to be conducted throughout all phases of the system life cycle. It is important to monitor risks because mission needs, system requirements, technology opportunities, and program status change frequently. It is especially important to continually monitor risks during NAS modernization because of the interdependencies among programs.

The NAS is an integrated collection of systems that deliver a set of capabilities to NAS users and NAS service providers. A change in one system can adversely affect others. Risk management reduces the number of situations that become problems as well as their consequences. The NAS Architecture is where interdependent program risks can best be identified, analyzed, tracked, and mitigated. Risk management will result in a greater percentage of projects being delivered on time, within cost, and that meet performance expectations.

Risk management is an integral part of program management, which helps implement a system successfully. It can be defined as a five-step process, that focuses on identifying risks, analyzing risks, prioritizing risks, mitigating risks, and tracking and controlling risks. These five steps are discussed in more detail below. The goal of risk management is to invest a small amount of money and time, relative to the total value of the program, to reduce the probability or impact of unplanned events by taking action before a situation becomes a NAS-wide issue. Risk management is preferred because the cost is lower to resolve a problem early, and the time available for developing and considering options is greater, which increases flexibility in dealing with situations.

6.4.1 Risk Management Process

The five steps of risk management are:

- **Identification.** Risks must be identified before they can be managed. One way to ensure more complete risk identification is to categorize the risks. The categories used for NAS modernization are:
  - *Technical.* Technical risks are present in a program whenever a new technology is being introduced. It is often uncertain if a system can be built with the required performance.
  - *Operational.* Operational risk is the likelihood that the system that is built will improve the performance of NAS users or service providers.
  - *Support.* Support risks relate to the ability of the system to be adequately maintained or operated as intended, including the adequacy of training.
  - *Cost/Benefit.* Cost risk reflects the likelihood that a program will exceed the acquisition program baseline (APB). Cost-benefit risk is the probability that the initiative or activity will not deliver the benefit for which it was developed.
  - *Deployment.* Deployment risk is the likelihood that, even though a system has been developed successfully, there will be delays in achieving full operating capability because procedures and policies for using the new capabilities are not in place.
- **Analysis.** Risk analysis quantifies the probability of the risk event occurring and the impact (consequences) on the program. The analysis phase includes evaluating program dependencies that contribute to risks by increasing the impact or certainty of a risk event. To understand the total effect of a risk and later define a priority, the risk exposure must be considered. Risk exposure is the combination of the risk probability and the risk impact. As a general rule, the architecture assumes the higher the risk exposure, the higher the priority.
- **Prioritization.** Prioritization helps to apply limited resources to effectively mitigate risk. Risk analysis estimates the risk exposure for various activities. Usually, the highest exposure risks are dealt with first. In addition to the probability and consequences of a risk event, the following factors are taken into account: time criticality of mitigation; time of consequences; the cost of mitigation activities; or the perception of the importance of the risk to the user community.
- **Mitigation.** Risk-mitigation activities on a single program are usually separate, parallel activities that attempt to reduce the likelihood that a risk event will occur, or reduce the consequences of a risk event if it occurs. Risk-mitigation activities include analyses, modeling, prototyping, human-in-the-loop experimentation, parallel alternative development, limited field testing, and other activities designed to increase the success of implementing a capability. Risk mitigation for interdependent activities can be more complex. It is critical for NAS modernization that the combined risks of multiple deployments be assessed as early as possible so that mitigation plans can be implemented.
- **Tracking and Control.** As programs that provide new or improved capabilities for the NAS proceed, their risks change constantly. Every program that is practicing risk management will perform risk tracking and control. Periodically, risks will be evaluated and reprioritized and the risk management strategies adapted accordingly.

6.4.2 Risk Mitigation in Free Flight Phase 1 CCLD

NAS evolution will use a spiral development process. FFP1 CCLD, the first spiral development step, is designed to mitigate risk and evaluate early user benefits at a limited number of sites. FFP1 CCLD capability deployment will occur simultaneously with, and depend on, other modernization activities in NAS Modernization Phase 1. FFP1 CCLD will identify and resolve some of the significant risks associated with the development/deployment of new decision support tools, including procedure development, training, human factors, and user acceptance.

Technical

The future NAS will be composed of multiple new integrated systems. For example, in the en route domain, Traffic Management Advisor

(TMA), CP, data link applications processor (DLAP), weather and radar processor (WARP), and Host/oceanic computer system replacement (HOCSR) will be connected to the NAS local area network (LAN). Consequently, there is a risk that one system could adversely affect the operation of other systems connected to the NAS LAN. FFP1 CCLD will help mitigate these risks through system engineering analysis, deployment, and evaluation at multiple select sites. Information security presents risks. Since many of the new systems employ open architectures and modem networking techniques to distribute and collect information, these systems are vulnerable. These vulnerabilities must be resolved in the early development stage so that risk and cost are minimized.

Operational

The concept of operations cannot be met without new procedures and policies. Information provided by new capabilities will introduce coordination risks that will require changes in NAS participants' roles and responsibilities. Substituting data link messages for voice messages from controller to pilots will require new pilot-to-controller acknowledgment procedures. The objective of CPDLC Build 1 is to test initial procedures and then refine and validate these procedures prior to national deployment.

New capabilities must be operationally acceptable in order for service providers and aircraft operators to use them. Even though the capabilities will have been demonstrated and simulated, there is still a risk that they may not be operationally acceptable. FFP1 CCLD will mitigate this risk through limited deployment and working out the human factor issues. This will help determine performance tradeoffs for operational acceptability and identify unknown human factor issues. Although the new capabilities that make up FFP1 CCLD are designed to produce benefits independent of deployment site, sites differ in many respects. There is a risk that specific capabilities may not be operationally suitable at other sites. FFP1 CCLD addresses this risk by deploying some capabilities to sites with different characteristics. Evaluating the operational suitability at various sites will help define the criteria for national deployment.

Cost/Benefits

Early user benefits will help determine whether to deploy the new capabilities beyond the limited number of FFP1 CCLD sites. The benefits must exceed the costs of implementing, deploying, operating, and maintaining the systems that deliver the capabilities.

Deployment

The deployment schedule will address the ability of users and service providers to accept and implement new systems in a timely manner. Concerns include training schedules, system integration into existing infrastructure, and availability of technical staff to perform the installation.

6.4.3 Risk Mitigation in Safe Flight 21

Safe Flight 21 will provide early field experience to determine the operational acceptability and benefits of proposed new CNS technologies and capabilities, thus mitigating national deployment risks. The following describes some of the risks to be mitigated.

Technical

Safe Flight 21 risk-mitigation areas include certification of avionics and ground systems, requirement stabilization, information security, systems integration, and standards.

Operational

Risk will be reduced through development and validation of new controller and pilot procedures. Validation of initial user benefits will be accomplished in an operational environment.

Cost/Benefits

Products used to provide improved capabilities will be assessed for reliability and ease of use. Safe Flight 21 will enable user avionics equipage costs to be accurately determined.

Deployment

Safe Flight 21 will mitigate deployment schedule risks by involving the user community in the development and use of new avionics and related operational capabilities. User recognition of the benefits derived from these new capabilities will encourage avionics equipage and ensure ground systems deployment in a timely manner. The schedule will be harmonized with the rate of avionics equipage. Experience gained through Safe Flight 21 is expected to expedite the certification of new avionics and ground systems.

6.4.4 Risk Mitigation in Capstone

Technical

Capstone risk-mitigation areas include initial certification of avionics and ground systems, requirement stabilization, systems integration, and standards.

Operational

Risk will be reduced through development and validation of new controller and pilot procedures. Validation of initial user benefits will be accomplished in an operational environment.

Cost/Benefits and Deployment

Capstone will provide the initial data collection for making risk-reducing decisions.

6.5 Summary

The Architecture Version 4.0 provides a disciplined, structured, phased approach to changing the NAS. The architecture uses appropriate program management techniques that rely on risk management. As described earlier, FFP1 CCLD, Safe Flight 21, and Capstone will serve to mitigate risks in modernizing the NAS. Using the five-step approach and adopting a spiral evolutionary strategy that includes FFP1 CCLD, Safe Flight 21, and Capstone, the NAS architecture applies sound risk-management principles to meeting the modernization objectives.

7 SAFETY

To maintain the confidence that the aviation community and the flying public have in the NAS, the FAA is addressing system safety issues associated with modernization. Aviation system safety is the top priority of the FAA, and it will continue to be the top priority as the NAS is modernized and as capacity, efficiency, and flexibility increase.

First, system safety will be enhanced through incremental implementation of new systems while legacy systems continue operation. Second, NAS safety will be enhanced as new technology is introduced and system safety principles are applied in their design. Human performance considerations will be incorporated in the advanced automation technology. New and improved technology will provide pilots and controllers with better information for flight planning and operations and increased situational awareness, and enhanced decision support tools will increase efficiency.

Situational awareness is essential to safe flight. Modernization aims to enhance navigation/station-keeping, in-flight collision awareness/avoidance, terrain and obstacle awareness/avoidance, airspace boundary awareness, weather awareness, and onboard surveillance. Other aircraft and flight planning related applications will also be provided. Advancements in technology will support situational awareness without taking pilots out of the loop and without reducing the time for essential functions such as scanning the airspace.

Safety will be built in from the beginning by identifying where modernization initiatives will require major changes in safety risk management procedures and by applying system safety principles to their development. System safety principles use risk management techniques to systematically identify safety-related risks and provide mitigation to ensure that these risks are eliminated or controlled to an acceptable level. The system safety process includes hazard analysis, risk assessment, risk mitigation, and risk management. Objectives of system safety programs are to design a systematic approach to make sure that:

- Safety is designed into the system in a cost-effective manner
- Hazards are identified, tracked, evaluated, and eliminated, or the associated risk is reduced to an acceptable level
- Historical safety data and lessons learned are considered and used
- Minimum risk is sought in accepting and using new technology, materials, designs, or operational techniques
- Actions are taken to eliminate hazards or reduce risks to an acceptable level
- Changes in design, configuration, or requirements are accomplished in a manner that maintains an acceptable risk level
- Significant safety information is documented, stored, and used in applicable designs and specifications.

The order of priority for satisfying system safety requirements and resolving identified hazards will be to:

1) Design for minimum risk
2) Incorporate safety devices
3) Provide warning devices
4) Develop procedures and training.

The high safety levels of our current aviation system stem from effective risk management, which is based on the following complementary factors:

- Redundancy in certified air traffic control equipment
- Recognized air traffic control standards and procedures
- Thorough controller and aircrew training and certification
- Thorough maintenance technician training and certification
- Evolutionary improvements in aircraft design, crew training, operational procedures, and supporting technologies.

These complementary factors are the foundation of safety-related risk management and the public's high confidence in aviation safety.

It is important to assess any changes in the NAS from a system safety viewpoint—for example, how changes will affect interfaces, interactions, and redundancies that contribute to the aviation system's inherent safety. Before use, each component of the new architecture will be thoroughly tested to ensure that safety is not degraded by new hardware, software, or procedures. This assessment is also required by FAA Order 8040.4.

7.1 NAS Capabilities

NAS modernization will enhance safety through more effective risk management in critical areas of the aviation system. Recently, the FAA's focused safety agenda, "Safer Skies," identified high-priority safety concerns. Additionally, the FAA administrator has established a risk management policy and has implemented safety risk management as a decisionmaking tool within the FAA. Modernization will strengthen safety risk management in several of these high-priority areas by reducing the potential for controlled flight into terrain and runway incursions, improving flow control of approach and landing operations, and providing better weather information. The following paragraphs describe specific architectural changes that can improve NAS safety.

7.1.1 Navigation, Landing, and Lighting

The navigation and landing portion of the NAS architecture provides system safety improvements by:

- Replacing existing ground-based nonprecision approaches (i.e., approaches dependent on horizontal guidance from ground-based navigation aids) with more precise Global Positioning System/Wide Area Augmentation System/Local Area Augmentation System (GPS/WAAS/LAAS) approach capabilities, which provide vertical descent guidance to all GPS approaches
- Combining GPS with cockpit electronic maps of terrain to enhance cockpit situational awareness.

Eventually, a GPS-based approach will be available at almost every location within the NAS, supported by airport development and the formulation of instrument procedures.

A review of National Transportation Safety Board (NTSB) accident statistics for the United States concluded that approaches with vertical descent guidance (precision approaches) are several times less likely to experience an accident than approaches that lack vertical descent guidance (nonprecision approaches). A related study by the Flight Safety Foundation came to the same conclusions for international air operations.[1]

7.1.2 Surveillance

The entire inventory of terminal primary radar systems will become digital as the airport surveillance radar (ASR)-11 is completely fielded, and ASR-7 and ASR-8 equipment is decommissioned. Digital radars, for technological reasons, are more capable of detecting smaller aircraft at low altitudes, particularly in background clutter conditions. ASR-9 and ASR-11 digital radar systems also provide an improved weather detection and display capability. These improved capabilities can improve safety in terminal airspace.

The entire secondary surveillance radar (SSR) inventory will migrate to a selective interrogation capability. This capability will be modified to acquire position and velocity data from aircraft equipped with automatic dependent surveillance broadcast (ADS-B) via ground-initiated communications broadcast (GICB).

GPS information will improve target-tracking accuracy and enhance the functionality of various air traffic control decision support system (DSS) tools, such as conflict alert, conflict probe, trial planning, descent advisor (DA), Final Approach Spacing Tool (FAST), etc. Improved surveillance accuracy and tracking, linked with DSSs, will significantly aid controllers in separating aircraft from other aircraft, obstacles, and special use airspace (SUA).

Cockpit display of traffic information (CDTI), incorporating ADS-B information, will display nearby traffic, further enhancing cockpit situational awareness and safety.

1. Based on a review by FAA's National Aviation Safety Data Analysis Center of the National Transportation Safety Board accident statistics covering 1983 through 1996 and a 1996 Flight Safety Foundation report covering worldwide commercial jet transport accidents, 1958–1995.

7.1.3 Communications

New digital communications systems, including data link, are expected to decrease verbal air traffic control (ATC) miscommunication of information such as headings, altitudes, or runway clearances. Flight information service (FIS) data link will provide other flight safety information such as current and forecast weather information, notification of navigational equipment status, airfield status, etc. Controller-to-pilot data communications allow controllers to communicate more effectively with aircraft in a congested voice radio environment.

Traffic information service (TIS) will support cockpit displays of other nearby aircraft and call attention to those that are on a converging or intersecting path. For time-critical applications, continuous and automatic information updates will be possible via data link services.

Safety can be improved in many areas by enhanced communications. For example, information about aircraft position is essential to situational awareness and collision avoidance. Aircraft flight object information and enhanced surveillance information will be necessary for flights in areas that do not have radar coverage.

Weather advisory information disseminated through automatic terminal information service (ATIS) and data link can give pilots more timely warnings of hazardous weather and other airport conditions. The next-generation air-ground communications system (NEXCOM) will improve voice communications and data link services, providing both on the same digital radios. NEXCOM will increase the number of usable radio frequencies, enabling better air traffic management.

7.1.4 Avionics

Increased navigational accuracy of GPS-based avionics and nearly universal availability of GPS signals are important improvements over today's navigation aids. GPS, WAAS, and LAAS avionics will provide approach course and vertical descent guidance to pilots for instrument approaches.

WAAS-augmented GPS will provide a navigational signal in space down to Category I (CAT I) minimums at suitably equipped airports. This capability alone is an important improvement over all previous nonprecision instrument procedures such as very high frequency omnidirectional range (VOR), tactical air navigation (TACAN), automatic direction finder (ADF), nondirectional beacon (NDB), and localizer (LOC). These nonprecision approach methods currently depend upon the pilot to establish a suitable rate of descent to arrive at the minimum descent altitude at or before the missed-approach point.

As a practical matter—and putting aside the traditional association of precision approaches with decision heights of 200 feet or less—all GPS procedures will be capable of being used to fly precision approaches (i.e., with both course and vertical guidance). Precision approaches are an improvement over nonprecision approaches in maintaining obstacle/terrain clearance. This satellite-based navigation capability could decrease risks associated with controlled flight into terrain—one of the most common types of fatal accidents in aviation.

WAAS can also improve the accuracy of ground proximity warning systems and, in conjunction with digital terrain data bases, could further reduce the risk associated with controlled flight into terrain.

GPS (augmented by WAAS to meet system safety, availability, and reliability requirements) is expected to be the basis for improved situational awareness through the use of ADS-B and CDTI. Satellite systems also improve navigation on the airport surface during reduced visibility conditions via a moving map display that helps flight crews maintain orientation, even with reduced visual references.

Data link services can aid pilots and controllers by providing quicker and more accurate data exchange. Weather data exchange will give pilots a greater understanding of the winds and weather in a planned flight path. Digital radios will enable clearer voice communication between pilots and controllers and are less susceptible to interference.

Modernization attempts to increase situational awareness and support future operations through human-centered decision support technologies for pilots, controllers, and planners.

7.1.5 Information Services for Collaboration and Information Sharing

Information sharing facilitates controller-pilot collaboration. Local and NAS-level common information services will be used to provide information to pilots and traffic flow planners. Better information can allow selection of the most effective route to destination and alternate airfield and can provide warning of hazardous conditions. Additionally, providing real-time weather information directly to aircrews is essential to identifying hazardous weather conditions. Flight safety can be enhanced by automatic, simultaneous broadcast to the flight deck and service providers of hazardous weather alerts for windshear, microbursts, and gust fronts, as well as icing, turbulence, and thunderstorm information. For the foreseeable future, voice transmission will also continue.

More timely NAS status information, such as runway closings, airport construction, or temporary obstructions, can help aircrews avoid hazards and be better prepared if navigation or airfield facilities become inoperative.

7.1.6 Traffic Flow Management

Traffic flow management (TFM) decision support systems (DSS) work to mitigate demand-capacity imbalances through early prediction and collaborative resolution. These systems will allow better use of system capacity without unsafely overloading either controllers or pilots.

7.1.7 En Route

Automated tools are expected to further improve collision avoidance and reduce operational errors and deviations. New DSSs, such as conflict probe, can monitor aircraft position, predict potential conflicts, and suggest resolutions further in advance than can current alerts. Traffic Management Advisor (TMA) will calculate a more efficient and orderly sequence of arriving aircraft as they approach the terminal area.

Other tools can send ground proximity alerts to help mitigate controlled flight into terrain risk and provide alerts to warn of potential flight into restricted airspace. The planned use of automatic dependent surveillance (ADS) in nonradar areas will extend the benefits associated with radar air traffic services to increasing portions of en route airspace.

7.1.8 Oceanic

The use of satellite communications (SATCOM) and high frequency data link (HFDL) by oceanic service providers and users will provide real-time communications and electronic message routing. This capability will constitute the basis for ADS in oceanic airspace and give controllers more accurate positional data on oceanic flights. This improvement should allow a reduction in separation distances and still maintain or improve safety over the current levels. New oceanic conflict probe and conflict alert decision support tools can be used to help service providers detect and resolve potential conflicts and help prevent controlled aircraft from entering restricted airspace.

7.1.9 Terminal

Controllers will use improved automated conflict detection tools and enhanced ATC displays to separate aircraft from other aircraft (those either on the ground or in the air) and from restricted airspace, terrain, and hazardous weather. Controllers will use integrated weather information, including windshear and microburst alerts, to assist pilots in avoiding hazardous weather and to improve the flow of traffic in terminal airspace. Tools, such as Controller Automation Spacing Aid (CASA) and Converging Runway Display Aid (CRDA), allow controllers to refine the arrival flow of converging aircraft to the primary airport, increasing airport capacity while maintaining safe separation standards. Advanced tactical flow control tools, such as active FAST and DA, promote a steadier flow of aircraft into the terminal airspace.

7.1.10 Tower/Airport Surface

New airport surface detection equipment (ASDE-3) combined with the airport movement area safety system (AMASS) will alert controllers to potential conflicts between arriving aircraft and surface traffic and between aircraft and vehicles at 34 high-use airports. Additional radar and conflict-alerting systems are being planned for other airports. Satellite-based navigation systems, including those augmented by LAAS, improve situational awareness for surface operations. Integrating ADS data with radar data and enhanced ATC displays for airport surface surveillance will further improve surface conflict detection.

7.1.11 Flight Planning

The Operational and Supportability Implementation System (OASIS) at the automated flight service stations (AFSSs) collects information from multiple weather sensors, FAA systems, and other sources. OASIS provides improved weather graphics, route-oriented briefings, notices to airmen (NOTAMs), and SUA notifications and warnings. This information is essential for flight planning and can be very important during a flight. Data link improves in-flight access to flight service station (FSS) specialists.

7.1.12 Weather

Improvements in detecting and forecasting weather can help aircraft avoid hazardous weather situations. The airport surveillance radar-weather system processor (ASR-WSP) expands NAS windshear detection and alert capability. The integrated terminal weather system (ITWS) integrates data from multiple sensors and sources to produce windshear, microburst, and gust front alphanumeric and graphic forecast products to provide improved automated weather information and predictions. Broadcasting ITWS information via the terminal weather information for pilots (TWIP) system to aircraft in or approaching terminal airspace also gives pilots a better opportunity to avoid thunderstorms, hail, icing, and turbulence. ITWS supports proactive rerouting to avoid windshear or severe weather.

In a similar manner, the weather and radar processor (WARP) will provide improved weather data for en route service providers. In particular, WARP provides the weather data from the Doppler next-generation weather radar (NEXRAD) to en route controller displays.

Weather information will be made available, via tailored broadcast or upon request, from a common network available to all NAS users. The FAA will make NAS status and existing weather data available to private data link service providers for the development of FIS products. Commercial providers may make basic FIS products available, at no cost to the government or the user, and may make value-added products available for a fee.

Current and predicted hazardous weather data will be integrated and presented on controller displays. Weather data down-linked from aircraft reporting in-flight conditions will improve weather forecasts. Integrated weather products will be uplinked to the cockpit, initially by FIS to assist pilots in avoiding hazardous weather. An improved and shared view of weather information among aircrews, controllers, dispatchers, and meteorologists enhances weather communications by increasing understanding of weather and permitting collaborative replanning of flights.

7.1.13 NAS Infrastructure Management System

The NAS maintenance workforce will have critical NAS component status information available for remote diagnosis of system problems. A fully fielded maintenance management system will allow technicians to provide more timely and effective maintenance of the NAS infrastructure. Greater availability, quicker restoration, and improved reliability of NAS infrastructure components will enhance the NAS.

7.2 Safety Metrics

Several data sources are available to assess NAS safety. The NAS safety metrics provide baseline information for the NAS as it is modernized. Tables 7-1 and 7-2 show safety trends for the years between 1990 and 1997 for a variety of safety indicators and some of the metrics presently used.

Safety measurement can be based on the record of lessons learned from accidents and incidents. Over the past 30 years, accident rates have decreased for large air carriers and commuter operations.[2] This is the result of both technological and operational changes within the NAS. The accident rate, however, is an after-the-fact measure, which uses past data as a yardstick, which can be

2. Based on National Transportation Safety Board accident statistics for U.S. commercial air carrier accidents, received from the NTSB Public Inquiries Section. This also applies to the worldwide commercial jet fleet, based on statistics released by the Airplane Safety Engineering Division of the Boeing Commercial Airplane Group.

PART II

Table 7-1. Accident Trends

Safety Indicator	Description of Aviation Accident Rates	Trend (1990–1997)
Large Air Carrier Accident Rates	This indicator compares the number of accidents involving all large air carriers (i.e., operating under Federal Aviation Regulation (FAR) Parts 121 or 127) to the number of flight hours and departures for these carriers.	Steady for 1990 through 1994 at a low rate; an increase for 1995 through 1997.
Commuter Air Carrier Accident Rates	Compares the number of accidents involving all commuter air carriers (i.e., scheduled carriers operating under FAR Part 135) to the number of flight hours and departures for these carriers.	Up from 1990 to 1991; steady from 1991 through 1992; improving from 1992 through 1994 at a low rate; an increase from 1995 through 1997.
Air Taxi Accident Rates	Compares the number of accidents involving all air taxis (i.e., nonscheduled air carrier operations under FAR Part 135) to the number of air taxi flight hours.	Steady.
General Aviation Accident Rates	Compares the number of accidents involving all general aviation aircraft to the number of general aviation flight hours.	Steady.
Mid-Air Collision Accident Rate	Compares the number of mid-air collision accidents involving all operator types to the number of flight hours for all operators (i.e., large air carrier flight hours + commuter flight hours + air taxi flight hours + general aviation flight hours).	About the same rate from 1990 through 1996, with a dip in the middle years; improvement in 1997.

Table 7-2. Incident Trends

Safety Indicator	Description of Aviation Incident Rates	Trend (1990–1997)
Pilot Deviation Rates	Compares the total number of pilot deviations to total system flight hours.	Down from 1990 through 1995; up in 1996 and 1997.
Near Mid-Air Collision Reports (NMACs)	Presents the total number of system reported NMACs.	Downward trend overall; slight rise in 1997.
Air Carrier Near Mid-Air Collision (NMAC) Rates	Compares the number of NMACs involving all air carriers (i.e., those operating under FAR Parts 121, 127, 129, and 135) to the number of air carrier flight hours.	Downward trend overall; slight rise in 1997.
Operational Error Rates	Compares the total number of operational errors to the total number of facility activities.	Steady.
Runway Incursion Rates	Compares the number of runway incursions that occur at airports to the number of operations at the airports.	Down from 1990 through 1993; up from 1994 through 1997.
Vehicle/Pedestrian Deviation Reports (VPDs)	The number of VPDs. A VPD is an entry to or movement on an airport movement area by a vehicle (including aircraft operated by a nonpilot) or pedestrian that has not been authorized by air traffic control.	Downward trend with fluctuations.

used to predict future behavior and assess risks associated with NAS changes.

System safety risk assessment provides a more proactive approach by identifying safety-related risks early and by applying risk elimination and risk control. This enhancement improves safety.

The NAS is monitored from a system safety approach that acquires accident and incident data. Examples of incidents include operational errors, near mid-air collisions, and pilot deviations. Incident data provide information about events that can lead to potential accidents. Additional metrics may be used over time.

7.3 Summary

Safety is improved through more effective mitigation of risks or elimination of underlying hazards. Extremely complex and effective mitigation strategies support the aviation system's inherent high safety level. The development of the aviation system's mitigation strategies has been incremental and evolutionary as improvements have been made in aircraft design, crew training, operational procedures, and supporting technologies. Potential hazards have been eliminated through design, safety devices, or procedures. Redundancy has been successfully used as a mitigation strategy to reduce the probability that failure of a single element will lead to an accident. This safety risk assessment process will continue as the NAS is modernized to ensure that existing risk is minimized and new hazards are not introduced.

NAS modernization has the *potential* to reduce the number of accidents. Accident rates will not decrease unless the capabilities described in the NAS architecture are implemented and a high percentage of aircraft are equipped with new avionics. Implementation, of course, is dependent on funding and the allocation of scarce resources. Acquisition and installation of new avionics is controlled by numerous users. Furthermore, even when implemented, the architecture's capabilities are not omnipresent; some are available only in selected airspace or at larger airports. A study[3] of particular reports of accidents involving turbulence, hazardous weather in the terminal area, airport surface operations, collisions between aircraft, and controlled flight into terrain indicates that accidents attributed to these factors can be reduced by NAS modernization.

3. *NAS Architecture and Safety*, a preliminary analysis performed by the FAA Office of System Development, January 1998, Wash., D.C.

8 HUMAN FACTORS

The human component of the NAS is a key element of NAS modernization. Focusing on human factors elements of new systems early in the acquisition process reduces costs, minimizes program schedule disruptions, and brings new benefits to NAS users earlier.

8.1 Human Factors Activities—NAS-Wide

A broad range of activities regarding the implications of human factors will be conducted to support NAS modernization. These activities involve both acquiring and applying the information necessary to capitalize on human capabilities and limitations that affect human-system performance in each domain. Human factors engineering research and application activities will be employed to identify and resolve risks and to assess costs, benefits, performance levels, and tradeoffs. Issues for which human factors research and application activities will be employed include:

- Computer-human interface (CHI)
- Controls, displays, and alerts
- Procedures, incremental changes to systems, and system component integration
- Workforce productivity, workload, usability, and task performance
- Training for new automation operation and maintenance; equipment, workspace, and workplace design
- Manpower resources and staffing; unique skills, abilities, characteristics, and tools; communications and teamwork; job and organizational design
- Human performance aspects of safety, health, and environmental considerations.

Through these activities, human factors will be systematically integrated into every phase of NAS modernization. While the range of endeavors undertaken to integrate human factors in the NAS is necessarily broad, six major activities are listed and described below:

- Life-Cycle Costs, Benefits, and Tradeoffs
- Human Performance Metrics and Baselines
- Consistent Computer-Human Interface Prototypes
- Human-in-the-Loop Simulations
- Task Analysis and Workload Measurement
- Workstation Integration.

In addition to its own efforts, the FAA will work with the National Aeronautics and Space Administration (NASA), the Department of Defense (DOD), and others to take advantage of their human factors research.

8.2 Life-Cycle Costs, Benefits, and Tradeoffs

Research (and the application of the results) is needed for more information on the costs, benefits, performance levels, and tradeoffs of alternative approaches to meeting NAS requirements. This activity will develop and apply sources of data and help integrate a human performance perspective into investment analysis and programmatic decisions. The activity will provide human factors information to conduct the necessary alternatives evaluations, assess current and future affordability, contribute to the tradeoff analyses and investment decisions, and resolve cost-effectiveness issues during solution implementation. Results of this activity include:

- Identification and description of human factors variables that impact costs, benefits, and tradeoffs (e.g., the types of operational benefits related to human performance on new and upgraded systems)
- Methods to predict and assess the relevant human factors variables and risks that significantly impact system performance (e.g., how to identify the risks of operator cognitive workload for critical functions/tasks in en route, terminal, traffic management, and oceanic domains)
- Algorithms to quantify human factors variables and their relationships (e.g., human-system performance cost-benefit estimating relationships for new display concepts)
- Information related to human factors costs, benefits, and tradeoffs (e.g., establishing the means to assess systems using historical and

evolving records, such as data on task analyses and training for deployed systems)

- Assessments of the tradeoffs associated with human factors, including personnel selection, staffing, training, and human-system performance.

8.3 Human Performance Metrics and Baselines

As new systems are acquired to replace or augment those currently deployed, human performance metrics and baselines will be developed. These metrics will be used to quantify current operational efficiency and effectiveness, facilitate market survey analysis, assess progress during system development and implementation, and support system performance tests and evaluation. Results of this activity include:

- Metrics to assess human and human-system performance (e.g., standardized metrics and measurement techniques for assessing operator/maintainer workload, staffing, and training for vendor solutions during market surveys)
- Methods to benchmark human-system performance, usability, and suitability (e.g., development and application of techniques, tools, and procedures for determining and mitigating potentially high levels of individual and team communication requirements)
- Ways to link varying levels of human performance to operational system capabilities (e.g., the measures of workload related to the maturity of a system's technology and CHI)
- Development of a comprehensive set of scenarios, system configurations, environmental measures, and simulation concepts for conducting baseline and subsequent assessments (e.g., operational scenarios for terminal operations to evaluate procedural changes)
- Baseline assessments and periodic measurements of NAS systems using human-system performance metrics.

8.4 Consistent Computer-Human Interface Prototypes

Studies have shown that the final cost of software and hardware depends largely on changes to the initial system design. Also, a disproportionate share of system changes are a result of human-system integration and CHI requirements. Without well-planned human-system integration, acquired NAS systems that employ commercially available solutions could result in increased software cost, higher training time, and greater operational complexity. Safety and productivity in the NAS will be enhanced through the development of common interfaces, consistent CHI, and compatible functions and procedures. Results of this activity include:

- Concepts and prototypes for compatible preplanned product improvements (e.g., compatible CHI for terminal and en route upgrades)
- Common CHI designs for systems migrating to common platforms and consoles (e.g., common function and form interfaces for systems transitioning into the NAS)
- Tools, techniques, and capabilities to rapidly prototype new CHI designs, assess vendor CHI solutions, and evaluate the impact of CHI alternatives (e.g., assess the strengths and weaknesses of new CHI designs and specifications for NAS applications)
- Technical standards and specifications for future CHI manufacturing designs (e.g., common core functions, display characteristics, and operational procedures for new Global Positioning System (GPS) receivers)
- Configuration management capabilities to compare CHI compatibility between system components and to design new systems' CHI.

8.5 Human-in-the-Loop Simulations

A method for scientifically predicting how a human would react and perform under certain conditions when operating or maintaining a new system is referred to as a "human-in-the-loop" simulation. Human-in-the-loop simulations of developing systems allow human-performance characteristics to be systematically analyzed and evaluated. Task loading and sequencing, information processing, and crew coordination need to be examined to identify and resolve potential risks and opportunities. Examining these areas will also provide an early indication of whether human performance associated with a system will support NAS performance requirements. Primary results of this activity include:

- Mission scenarios (developed for various domains, with sufficient fidelity to ensure objective, quantifiable measures) that will allow examination of controller and pilot performance in a realistic environment
- Simulation results/findings that verify critical tasks, validate task analyses, refine procedure designs, assess training regimen designs, and identify implied operation and maintenance diagnostic and problem-solving activities
- Comprehensive and consistent assessments and measurement of human performance within systems and across the integration of systems.

8.6 Task Analysis and Workload Measurement

Much of the work associated with task analyses and workload measurement is focused on “time required” versus “time available” for operator and maintainer performance. The measures of time and accuracy (e.g., error rate) will be used with other measures to assess and improve human-system performance. These measures will supplement subjective rating scales that provide insights into user attitudes, but do not always correlate with objective measures of performance. Primary results of this activity include:

- Validated tools and techniques, both objective and subjective, to provide measures of the cognitive task and workload assigned to operators and maintainers
- Data bases to support development of task analyses and workload measurements
- Resulting analyses and measurements that describe human-system performance at the required component level of the system.

8.7 Workstation Integration

Human factors activities related to workstation planning, analysis, and implementation will ensure that the design of the workstation is suitable for its intended application and use by the system operator and maintainer. Primary results of this activity include:

- Methods to describe and control the design of complex workstation configurations
- Design guidelines for systematic integration of a variety of control and display devices to enhance operator and maintainer performance
- Design and implementation analyses, alternatives, and recommendations for configuring future workstations and NAS workstation environments.

8.8 Summary

These human factors activities provide a framework for developing and implementing human-system performance advances in the NAS. It is important to recognize that the description of these activities represents only an outline of the necessary steps toward achieving the NAS human factors objectives. While the description of the human factors work in support of NAS development may be categorized into broad, generic areas and activities, the work that is performed must be tailored to the specific systems and issues to be addressed in each domain. Detailed human factors research and application efforts within each domain are required to institutionalize the consideration and resolution of human performance issues and reduce many of the operationally significant human performance challenges facing the nation’s aviation system. An overview of the work to be accomplished in each domain is discussed in the domain writeup.

9 INFORMATION SECURITY

The current NAS is a collection of systems, each evolving independently over time to support a major NAS functional area. As modernization proceeds, these independent systems will migrate toward an open architecture with more interaction between systems both inside and outside the NAS. While numerous benefits can be gained from open systems and standard data formats, the risk of unwanted disruptions of critical NAS services also increases. To decrease this risk, the architecture identifies key risk areas and proposes mitigating strategies.

Information security (INFOSEC) is integral to the NAS architecture. While not an obvious contributor to NAS functionality, INFOSEC is essential to ensuring the availability, integrity, and confidentiality of NAS operations. To protect NAS systems, INFOSEC must be engineered so that NAS functional performance and cost tradeoffs include appropriate protection whenever sensitive systems are involved. This includes, for example, all processing, storage, and communication of air traffic control (ATC) information. This section provides a high-level INFOSEC approach, but does not discuss detailed protective measures.

9.1 Need for Information Security

Safeguarding information systems used for NAS operations is an essential part of the NAS architecture. In addition to data directly related to ATC operations, sensitive or proprietary information pertaining to NAS users must be protected.

An effective NAS INFOSEC architecture encompasses many activities, ranging from policy to testing. These activities must be covered over the life cycle of NAS systems. The INFOSEC aspects of the architecture must define investment strategies that balance threat and potential vulnerabilities against investment costs.

9.2 Evolution of Information Security

The NAS is evolving to embrace new systems and open systems. This evolution has resulted in an increased use of common industrial standards and commercial off-the-shelf (COTS) products and a decreased use of proprietary systems. These changes emphasize the need to manage security interfaces among systems and to fully utilize the security features of COTS products to protect the NAS.

9.3 Scope of NAS Information Security

An information security architecture ensures the use of appropriate and uniform security measures across NAS subsystems, elements, and services. The architecture addresses NAS operational systems, as well as any administrative systems connected to operational systems. Interfaces between these and other systems (e.g., user systems or other government systems) are also addressed. Public networks, which are used to transfer information between facilities and systems within the NAS, are considered vital avenues of access into the NAS. The FAA will focus on ensuring information security at the interface points between the NAS and public networks.

Since the NAS is a “system of systems,” security between different systems—as well as security within individual systems—must be emphasized. Processing, storing, and transferring information within and across systems must be secure. This prevents attacks that use one weak system as an entry point from which to probe and penetrate other NAS systems. As shown in Figure 9-1, the goal of INFOSEC is to protect the availability, integrity, confidentiality, and authenticity of data used in NAS operations.

9.4 Information Security Approach

Analyses of NAS systems, along with assessments of security products and services, are used to develop security profiles. System acquisition personnel use these profiles to match characteristics of particular systems with appropriate security products and services. Coupled with appropriate policies and procedures, profiles provide an integrated approach to information security in the NAS.

A management structure will administer security processes from an operational viewpoint and participate during the acquisition phase of the life cycle. A systemwide concept of operations (CONOPS) for information security ensures uniform security measures within individual systems and compatibility across systems.

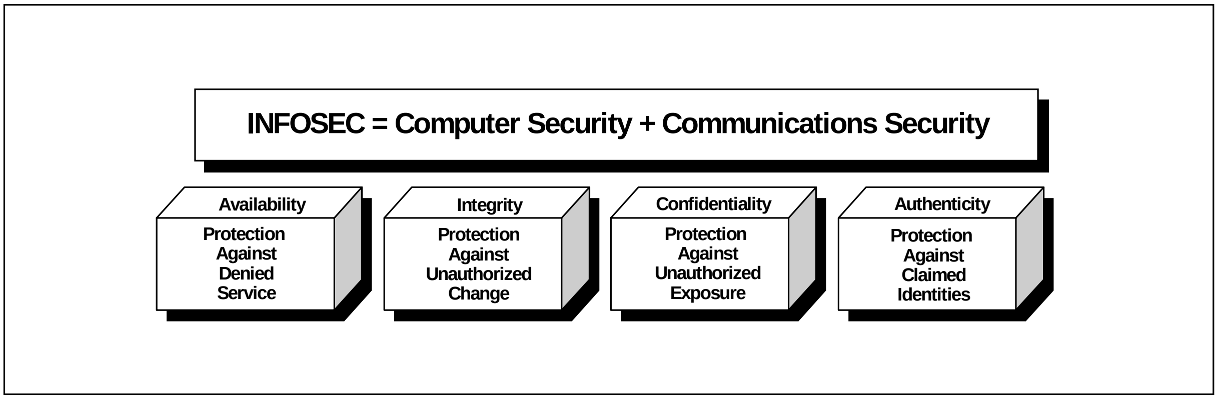


Figure 9-1. Goal of Information Security

9.5 Information Security Elements

INFOSEC policy, CONOPS, and security engineering process drive the security approach. Figure 9-2 illustrates the relationships among these elements. As a component of the NAS architecture, the security architecture provides high-level technical guidance on security-relevant structural aspects of NAS systems.

INFOSEC policy establishes basic ground rules to guide the CONOPS and Security Engineering Process, and thus guide the security approach.

The INFOSEC CONOPS is aligned with future directions for air traffic control operations, as well as with the technical and organizational changes associated with a centralized approach to NAS infrastructure management. The INFOSEC CONOPS defines functions to support the following objectives:

- Enforce INFOSEC policy
- Maintain preparedness for prompt response to rapidly changing risks and security technologies.

The INFOSEC engineering process defines acquisition-relevant INFOSEC functions that are consistent with:

- Progressive realization of NAS security protection through sound security practices

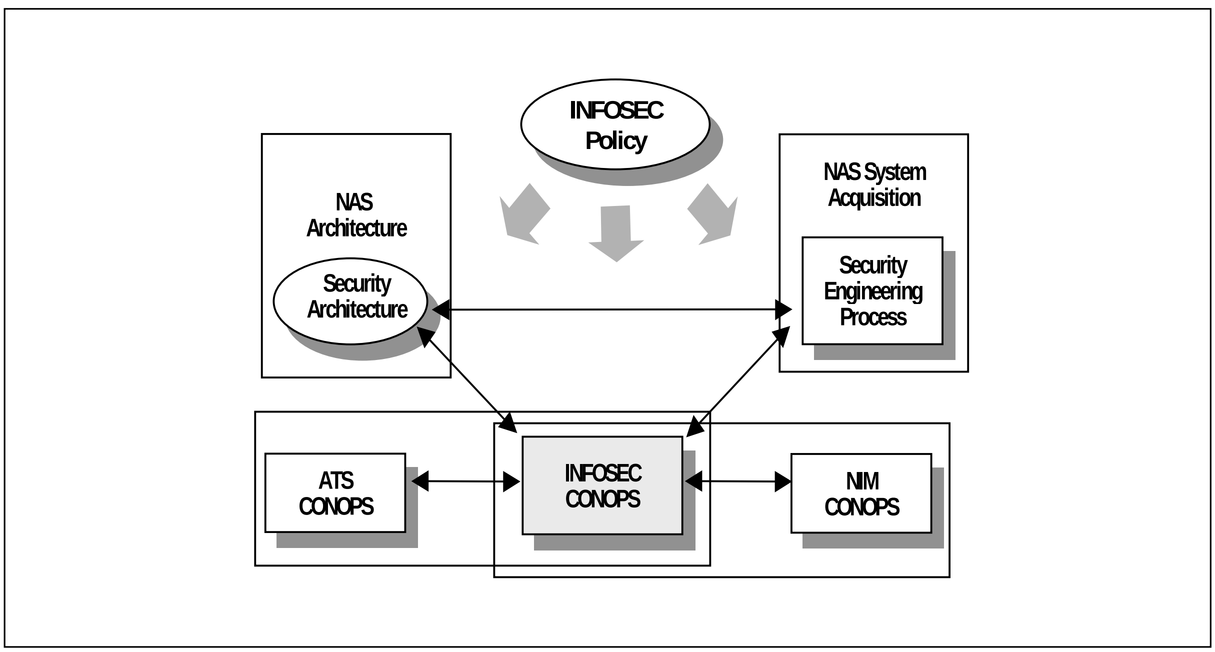


Figure 9-2. Relationships Between Major INFOSEC Elements

- Revised FAA acquisition procedures
- Fielding systems for operational use without introducing new vulnerabilities.

9.6 Technical Capabilities

As a part of the NAS architecture, INFOSEC capabilities will support multiple logical barriers to provide a layered defense of NAS systems. One barrier consists of countermeasures integrated into individual systems to protect local operation.

Another barrier is created by adding countermeasures at the entry points where external systems connect to the NAS. Countermeasures include firewalls, proxy servers, and security gateways to control communications access in a distributed network. This barrier secures NAS operations against unauthorized access from external systems. A further barrier consists of countermeasures to authenticate users within communities-of-interest, such as air traffic control, air traffic management, and flight services. Common security services support the various barriers. For example, one service involves audit collection and system monitoring, and another service provides tools for security administration.

9.7 NAS Functional Areas

9.7.1 Communications

Air-air, air-ground, and ground-ground communications have specific characteristics that must be evaluated separately to determine their contribution to vulnerability and risk to the systems within the domains over their life cycles. The FAA information security engineering process will be applied in determining communications vulnerabilities and the required countermeasures needed to control communications-related risks. Future security services will preserve the availability, integrity, confidentiality, and authenticity of NAS communications.

9.7.2 Navigation, Landing, and Lighting Systems

With precision landing services eventually depending primarily on the use of Global Positioning System (GPS) signals augmented by Wide Area Augmentation System (WAAS) and Local Area Augmentation System (LAAS) differential correction signals, there is a need to protect these systems from harmful interference. The FAA is currently working to develop safety and system security countermeasures for satellite-based navigation and landing systems to prevent or mitigate interference. The backup navigation and landing system capabilities that are needed to protect against intentional jamming and signal interference will be defined.

The FAA and the users, through RTCA, Inc., are currently reviewing the backup requirements for GPS. The likelihood of interference is the primary threat to GPS navigation. Any backup determined as being necessary must support at least nonprecision approach capabilities, for it is in the landing phase that interference will be most disruptive.

9.7.3 Surveillance

The evolution of the surveillance system architecture introduces new information security risks for automatic dependent surveillance broadcast (ADS-B) surveillance reports. Potential surveillance security concerns include interference with WAAS correction signals, which affects the accuracy of ADS-B data; interference with GPS signals, which denies ADS-B service in the affected area; and message flooding of the surveillance system.

Security features are needed for the surveillance systems to ensure continued operations during these types of events, which is one of the reasons for continuing secondary surveillance radar (SSR). Provisions will also be considered for detecting unusually high message activity on surveillance inputs and generating a warning. Sharing surveillance information will necessitate special security provisions, including access control, user verification functions, and restrictions on the types of information that each user group can access.

9.7.4 Avionics

Avionics is the primary airborne component of the communications, navigation, and surveillance systems. The security considerations that apply to the avionics interface with these systems are summarized below. Using the NAS information security engineering process, the integrated product team (IPT) will work with the NAS Information Security Program during the entire life cycle of a fielded system, especially during functional upgrades and technology refresh, to identify the need for protection mechanisms.

- *Communications.* The next-generation air-ground communications system (NEXCOM) radio will be used to exchange real-time, safety-critical flight clearance information with the cockpit. The NAS information security engineering process will identify security provisions and countermeasures to be incorporated in the NEXCOM system design.
- *Navigation.* GPS, WAAS, and LAAS will be used as the primary means (systems) of navigation. Intentional and unintentional interference with GPS signals may result in a hazard that affects many aircraft simultaneously. This potential problem will be fully evaluated within the overall GPS, WAAS, and LAAS operational evaluation programs.
- *Surveillance.* The NAS architecture includes an automatic dependent surveillance (ADS) position reporting capability. Security provisions will be developed against possible interference and erroneous data transmission.

9.7.5 NAS Information Services for Collaboration and Information Sharing

Security will become a more complicated issue as the NAS-wide information network evolves. The sources and users of electronic data will increase substantially, as will the quantity and types of data available. Protecting the integrity and privacy of information will be critical to NAS-wide information network effectiveness (i.e., users must have confidence in data they access and that proprietary data are protected). New security systems and procedures will be implemented. Authorized users will have access to information—whenever and however they require—and unauthorized individuals will be denied access.

9.7.6 Traffic Flow Management

The traffic flow management (TFM) system allows users to obtain NAS information, electronically transfer flight plan data, and develop flight plans collaboratively. The TFM system receives, stores, and disseminates sensitive data from airline operations centers (AOCs), which will require solid information security measures. These security measures include logical separation of administrative and operational data, protection of sensitive AOC scheduling data, Internet access controls, firewalls, role-based access controls, and security gateways between the TFM network and any connected, nonsecured systems.

9.7.7 En Route

En route automation will be extended to support collaborative processing, flexible airspace structures, dynamic routes, and self-separation. En route technology will transition from relatively closed systems to open systems. Communications among systems will increase significantly, and data messages will replace many existing air-ground voice communications. New types of data structures will be implemented, and new classes of users will need to work with en route data.

Throughout en route modernization, service providers and users will need to identify appropriate security services. These services include authentication to protect the system from unauthorized access, integrity to protect messages containing sensitive information from corruption, and encryption to protect the privacy of data or to enhance authentication. Additionally, security training and administration will be the primary protection mechanisms during the operations and maintenance phase of the life cycle.

9.7.8 Oceanic and Offshore

Two classes of security are relevant to the oceanic system. The first is protection of the air-ground and ground-ground communications links. The second is protection of the ground-based components of the oceanic systems, which include automation and communications subsystems. The key services are user identification and authentication, access control, and an interface protection mechanism.

9.7.9 Terminal

The terminal domain contains several sensitive decision support systems that require security services. These services include authentication to protect the system from unauthorized access, integrity to protect messages containing sensitive information from corruption, and encryption to protect the privacy of data or to enhance authentication. In addition, security training and administration are key protection mechanisms during the operation and maintenance phase.

9.7.10 Tower and Airport Surface

The tower/surface automation and communications subsystems include a surface movement adviser (SMA) system and an air-ground tower data link service (TDLS). These systems must be protected against security breaches. For example, the SMA system will interface with AOC facilities at airports. Hence, there is a need to protect schedule and aircraft movement data on the SMA communications circuits and in the FAA and airline data bases.

Security concerns include unauthorized user access and modification or destruction of sensitive information used for surface operations control. Another concern is the air-ground data link, which will handle safety-critical clearance and real-time messages. Potential security breaches include unauthorized clearance transmissions and modification of messages on ground links. Provisions to mitigate security risks may include installation of security gateways between the FAA operational system and outside users and between the NAS information system and the TDLS access controls; message origin and message traffic verification; and security protection of surface control and movement data bases.

9.7.11 Flight Services

Flight services interacts with pilots and agencies outside the FAA. To meet its objectives, flight services must also interface with other NAS systems, including the weather and radar processor (WARP), the weather message switching center replacement (WMSCR), the en route automation system, and traffic flow management systems. Thus, the flight service system (i.e., the Operational and Supportability Implementation System (OASIS)) needs security services that include access control, user identification, and security gateways to protect availability, integrity, and confidentiality for itself and other interconnected systems.

9.7.12 Aviation Weather

Weather products are received both from FAA sensors, the National Weather Service (NWS), and commercial vendors. Weather messages flow among the FAA sensors, the integrated terminal weather system (ITWS), WARP, operational ATC systems, and the user community. Weather systems require protection against injection of false weather messages, unauthorized access, and unauthorized modifications of weather data bases. Security provisions for the weather subsystem will include access control, message sender authentication, and audit functions to record all messages and to identify the source of each message.

9.7.13 Infrastructure Management

NAS Infrastructure Management (NIM) tools interface with all other NAS systems, and its security access must be protected. For this reason, the management and control of NAS security services is a logical candidate for future inclusion in the NIM architecture. NIM tools could be used to collect NAS-wide subsystem security data for reporting and auditing purposes and to perform NAS-wide intrusion detection.

Within NIM tools, INFOSEC requirements are based on the NIM protection profile and vulnerability assessment. Meeting requirements for service availability, access control, authentication, nonrepudiation, and confidentiality will ensure adequate security for NIM tools. In particular, appropriate security gateway services are available to provide proper access control between NIM tools and other NAS systems.

Security management will allow the FAA to protect NIM tool data via user identification, authentication, and access control mechanisms. NIM tools could also support NAS-wide security management, such as detecting and logging NAS infrastructure security violations for reporting to FAA management.

9.8 NAS Information Security Cost

The FAA's estimated costs for NAS information security modernization are depicted in Figure 9-3. These costs include initial estimates for developing INFOSEC requirements and limited IPT support. The NAS INFOSEC process is awaiting investment analysis and Joint Resources Council (JRC) determination.

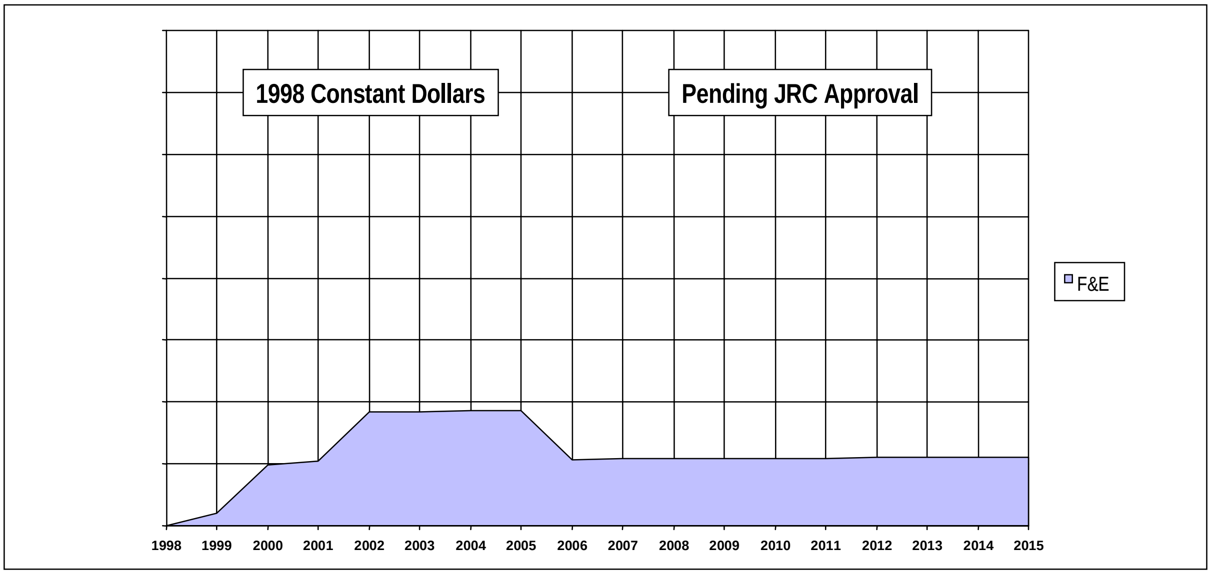


Figure 9-3. Estimated INFOSEC Costs

9.9 Summary

The present NAS is robust and extraordinarily resilient. NAS modernization includes the addition or revitalization of many programs. On the one hand, these programs bring new capabilities that enable future benefits. On the other hand, expanded functionality, greater connectivity, and well-understood commercial technology call for increased INFOSEC vigilance. The future NAS must implement a coherent INFOSEC architecture that mitigates these risks. Protection must extend throughout a system's life cycle. By applying sound INFOSEC principles during planning and design, the future NAS will retain its present resilience while addressing future concerns at acceptable costs.

The *National Airspace Architecture Version 4.0* does not provide specific architecture details for INFOSEC. This information is considered sensitive and would increase NAS vulnerability. The information security architecture is provided on a need-to-know basis.

The next section describes the role that research, engineering, and development plays in the modernization process. Successful research efforts are the key to unlocking the potential of new and, in some cases, yet to be discovered technologies.

10 RESEARCH, ENGINEERING, AND DEVELOPMENT

While numerous technologies employed during the early phases of NAS modernization are mature and well understood, many proposed possible paths for the later stages of modernization are just now emerging. Research, engineering, and development (R,E&D) activities will play a major role in assessing emerging technologies and discovering more advanced technologies that could be employed in modernization. This section describes the research efforts needed to fully understand and exploit the new and emerging technologies described in this architecture.

The FAA R,E&D program develops and validates technology, systems, designs, and procedures, along with supporting the agency's strategic requirements determination process. Today, the NAS is under heavy pressure to keep pace with rising traffic demand, needs for essential safety and security improvements, airspace user requirements for more flexible and efficient air traffic management operations, and demands for further mitigation of the environmental impacts of aircraft operations. As air travel increases, the agency's research and development work will take on added significance.

To meet these future challenges, the FAA employs a comprehensive, agencywide R,E&D investment analysis process to ensure that available resources remain customer-focused in terms of "outcomes" and "outputs," as mandated by the Government Performance and Results Act (GPRA) of 1993, and that these resources are targeted on the highest-priority activities.

The R,E&D program is divided functionally into seven areas. These areas are: Air Traffic Services, Airport Technology, Aircraft Safety, Human Factors and Aviation Medicine, Aviation Security, Environment and Energy, and R,E&D Program Management.

10.1 Air Traffic Services

The Air Traffic Services (ATS) R,E&D program is part of an integrated strategy intended to increase the scope and effectiveness of air traffic services at the most economical cost. ATS research is the agency's preferred means of leveraging its ATS investments for improved services, procedures, and infrastructure. ATS research integrates new concepts and technology, as required to meet demands for improved safety, efficiency, and productivity. The ATS RE&D programs yield operational concepts, human factors and performance guidance through simulation and analysis, standards for application of new technologies, prototype developments and evaluations, and software products for integration into current and future operational systems.

Listed below are the specific ATS research activities required for the modernization efforts detailed for each domain of this architecture (as described in Part III). The activities are identified by the appropriate modernization phases based on the time required to perform the activity and the completion date required to support enhancements to existing operations and deployment of future systems, as detailed in the NAS modernization schedule. As a result, this architecture represents a completely integrated program planning document depicting the most efficient and cost-effective approach to achieving the desired capabilities. If appropriate funding is not approved for R,E&D activity, there likely will be delays in the associated development schedule.

Currently, the FAA is reassessing the R,E&D program due to Congressional funding authorization actions. ATS services research is now funded by the facilities and equipment (F&E) budget. Although this will have some impact on the plan, the overall philosophy of the research activities that will be implemented out of F&E is consistent with the plan laid out here.

10.1.1 Navigation, Landing, and Lighting Systems

Phase 1 navigation and landing R,E&D will evaluate and develop the guidelines and procedures for the Global Navigation Satellite System/flight management system (GNSS/FMS) (or equivalent system) for precision arrival and departure paths. Standards, including minimum operational performance standards (MOPS) and technical standard orders (TSOs), will be developed for the Wide Area Augmentation System (WAAS) and Local Area Augmentation System (LAAS) technologies to support their implementation into the NAS and to promote international acceptance.

Research will be conducted on the procedures, specifications, and design for a redundant system.

Other R,E&D activities will include investigating the use of security services to guarantee the availability and integrity of navigation services. As the ground-based very high frequency omnidirectional range (VOR) infrastructure is phased-down, a set of named grid points[1] will be established to replace the VOR and fix locations. R,E&D will look into developing a low-cost runway lighting system to support the expanded capabilities provided by satellite-based navigation.

Phase 2 research will investigate alternative satellite-based configurations for providing navigation services. It will also investigate an inexpensive ground-based navigation system for providing selected backup capabilities.

10.1.2 Surveillance

The goal of surveillance research is to extend surveillance, using satellite-based position reports, to nonradar and surface environments and to provide a more cost-efficient and safe surveillance service for the NAS. Services stemming from this research include extending surveillance to these environments to improve situational awareness of both service providers and flight crews, ensuring that this coverage includes all operating aircraft. The planning within the surveillance architecture indicates that automatic dependent surveillance (ADS) will evolve to be the principal surveillance reference and a key to NAS capacity enhancement.

In addition to demonstrating ADS technology during the Safe Flight 21 program, Phase 1 research will investigate the best means for integrating ADS into the NAS ground-based infrastructure and obtaining the operational benefits associated with ADS. Development of an ADS ground system design—including standards, procedures, and system-level specifications—will then proceed. As a means of improving target position accuracy, research will identify the types of data to be fused and how and when they will be fused—leading to the development of a system specification.

As surveillance systems evolve to provide greater accuracy, research will need to determine the benefits, procedures, and human factors impact of reducing separation standards.

Phase 2 research will define backup strategies—given that surveillance and navigation merge when using the Global Positioning System (GPS) as a source for both. The architecture requires and designates at least two complementary means of surveillance in each domain. This work will study alternative approaches and lead to the validation of a selected solution. Before the end of the useful service life of the airport surface detection equipment (ASDE)-3 surface surveillance radars, a research effort will support development of a low-cost strategy for tracking all vehicles on the active airport surface.

Future research will investigate alternatives for replacing the terminal radar/beacon systems, terminal Doppler weather radar (TDWR), and other terminal surveillance sensors with a single system, upgrades of a present system, or a different type of service.

10.1.3 Communications

The goal of communications research is to improve aviation-related information exchange between service providers and all users of the NAS with greater efficiency and at lower cost. This information exchange will be used to enhance situational awareness for both the flight deck and service providers in all domains. Based on the extensive use of data link envisioned for the future, specifications will be developed for communication links, message protocols, avionics requirements, and certification of service. Associated cost-benefit analyses will be completed. Data links will be developed to integrate the aircraft FMS capabilities with the ground-based decision support automation, which will allow more efficient operation of the aircraft and the air traffic control (ATC)/management system.

Phase 1 efforts will include human factors analysis that addresses the flight deck and ground systems associated with data link and the viability of operational procedure enhancements made possible by data link. Additionally, a communications

1. Named grid points will provide a common reference for fixed ground locations.

strategy with associated cost-benefit analysis will be developed to provide NAS-wide information service data to all interested parties for their use in operating within the NAS. Because the Agency has plans for increased access to more information, Phase 1 research must be conducted to develop information security strategies for inter-facility, ground-ground, and air-ground communications. Communications research is also required to develop domestic and international digital signaling standards for current and future ATS voice switches.

In Phase 2, the availability of low earth-orbiting/medium earth-orbiting (LEO/MEO) satellite networks will allow satellites to be used for new applications, with the cost of these services expected to decline. Research will investigate a satellite communications strategy for air-ground communications, including FAA-owned and -leased systems and GPS enhancements.

Alternatives and methodologies studies will be conducted for the aeronautical telecommunication network (ATN) to examine the system conditions required for optimal performance of each communications scheme, as well as the degree to which those conditions meet the requirements. The performance and capacity of the designed ATN will then be validated using actual data from an implemented integrated system. This validation will help ensure that, for strategic planning purposes, any ATC service provider can communicate with the flight deck of any aircraft, regardless of the aircraft's location.

Department of Defense (DOD) systems that incorporate the latest, most efficient, and effective technologies offer great potential for economically accommodating a variety of civil as well as military air-air and air-ground communications needs. The systems also demonstrate that continued cooperative FAA and DOD system development and procurement offer a clear way to avoid duplication of effort.

10.1.4 Avionics

To realize the full benefits of modernization, users must equip with new avionics. In Phase 1, research will examine the minimum avionics required—and the cost involved—to obtain various levels of NAS services. The program will develop recommendations for improving the avionics certification and testing process, including reengineering the certification process for efficient, affordable certification. Research efforts will study the development of standards, certification processes, and technology applications intended to lower the cost of avionics and improve safety and efficiency through higher levels of avionics capability and equipage for the general aviation (GA) community.

In conjunction with the Human Factors Research Program, research will investigate the human factors issues associated with using multifunction displays to support situational awareness. A major focus of human factors research will include assessing how to best use the limited panel space available and assess the effects of new avionics on single-pilot operations. Standards and procedures for pilot separation assurance in cases such as station-keeping over ocean and on final approach will be investigated.

A study will also examine the range of services provided to aircrews by automatic dependent surveillance broadcast (ADS-B), as well as related aircrew procedures. Avionics research goals include improving flight deck situational awareness through cockpit display of traffic information (CDTI) and providing timely information about weather, flight plans, predeparture clearances, and taxi path assignments. Flight deck utilization of automatic weather alerts and graphical weather data will be examined.

To support search and rescue efforts, a program will develop emergency locator transmitters (ELTs), which transmit aircraft identification and GPS-based position information.

Research will result in improvement or development of the following avionics services.

Navigation and landing enhancements include:

- Increased use of satellite-based radionavigation routings
- Implementation of additional FMS-guided procedures
- Location with reference to terrain obstacles and special use airspace (SUA)
- Taxi routes and position on the airport surface

- Landing guidance to broad areas (i.e., precision and nonprecision, decelerating, curved, and segmented precision approaches (for fixed wing and helicopters)).

Surveillance and user-supported separation enhancements include:

- Tracking of all vehicles on airport surface (ADS-B, infrared, etc.), based on performance impact assessment for controllers and/or pilots
- Position of all close-by aircraft
- Station-keeping in selected oceanic airspace to reduce separation standards and provide in-trail climb and in-trail descent
- Transfer separation assurance to the cockpit for some simultaneous approach operations
- Taxi routes and position on surface provided to and monitored on the flight deck
- Station-keeping on final approach.

Communications enhancements include:

- Data link capabilities on airport surface
- Predeparture clearances by data link
- Altitude, heading, and speed assignments; frequency and transponder code changes; and certain clearances provided by data link to aircraft
- Rerouting and clearance amendments
- Planning tools and digital negotiation capability for tactical and strategic replanning
- Access to weather data and ability to update flight preference in the flight object
- Performance and intent data automatically from onboard systems (i.e., FMS).

Weather enhancements include:

- Graphical weather display available to the cockpit
- Improved weather information from a common weather data base shared between NAS service providers and users
- Fully automated terminal information service (ATIS) and terminal weather advisories delivered by voice and data link
- Aircraft downlink of winds aloft, humidity, temperature, and turbulence.

Additionally, new areas of research will be investigated as experience is gained with new cockpit avionics and procedures.

10.1.5 Information Services for Collaboration and Information Sharing

Phase 1 research will support evaluation of information requirements for the operational concept and implementation of the NAS-wide information service and the flight object. Standards and procedures will be developed to support implementation of information services that will enable greater information sharing between NAS users, leading to increased collaboration and improved decisionmaking.

Phase 2 research will focus on information distribution and access, including large storage technologies, data warehouse technologies for real-time decision support combined with intelligent distribution, and search and access technologies in the object-oriented world. Research into seamless interoperability with data integrity built in is essential for one NAS-wide coherent homogeneous system of systems.

10.1.6 Traffic Flow Management

In Phase 1, research will focus on developing expanded methods for cooperatively managing demand capacity imbalances with the users.

In Phase 2, tools to support the real-time management of alternative airspace designs will be investigated. Additionally, the goal in Phase 2 is to develop information and tools that can be used at all levels of the traffic management system so that capacity constrictions can be identified and solved at the most appropriate level.

The Phase 3 research goal is to provide decision support system (DSS) tools to service providers, flight crews, and airline operations centers (AOCs) for strategic air-ground traffic flow management (TFM) collaborative decisionmaking (CDM) and problem resolution. Some tools could include 4-dimensional flow analysis and flight object identification. These tools will help ensure that any imposed flow restrictions are necessary and executed effectively. Improved methods for identifying and predicting dynamic density prob-

PART II

lems will be designed. Postflight analysis must provide users and service providers with information about NAS performance strategies to optimize future performance.

10.1.7 En Route

The goals of en route research are implementation of separation standards matched to the accuracy of the positional information available, to relieve frequency congestion, and provide conformance monitoring of the flight profile. Achieving these goals will allow a shift in controller workload and assist controllers in separating aircraft from weather, which will increase throughput in en route airspace. Throughput may also be increased by transferring separation assurance to the flight deck in certain situations and allowing more user-preferred trajectories to be flown. The research efforts that support the en route domain will focus on greater utilization of the aircraft flight data management system, continued access to expanded flight information, improved decision support tools, and enhancements of data link applications to send and receive data in a more intelligible form.

Phase 1 research will evaluate airspace design alternatives for reduced vertical separation while accounting for the need to accommodate non-equipped aircraft in the airspace. Decision support tools for 4-dimensional flight profiles, hazardous weather, and ADS intent data as well as improved trajectory design tools will be developed to enhance aircraft monitoring and conflict prediction. Research will investigate methods of more precise separation and flight progress monitoring and of dynamic route structuring adapted to flight-level winds, hazardous weather, airspace demand, and user preferences.

In Phase 2, research will be conducted to validate the concept of dynamic sectorization of airspace to best match controller and traffic workloads. With the move to data link, design concepts will be investigated to determine how altitude assignments, frequency changes, and limited numbers of clearances can best be provided. Supporting en route controllers with an enhanced conflict detection capability, decision support software will be designed to monitor an aircraft's conformance to its intended profile. Research efforts will also look at more effective means of displaying flight progress information and concepts for other backup modes of operation.

In Phase 3, research will evaluate the flight object to determine how its detailed flight plan and trajectory information can be utilized to provide additional benefits to users and service providers. An effort will be made to determine how to probe all flight profiles when major environmental changes occur and how to provide access to this information for the flight deck, AOCs, and service providers to facilitate the strategic replanning process. Tools that will recommend flight profile changes based on present and predicted environmental changes will be investigated. Additionally, research will look at how to evolve the oceanic, en route, and terminal domains into a consistent, seamless operational environment that provides more precise monitoring of separations and flight progress.

10.1.8 Oceanic

A primary goal of oceanic research is to investigate procedures and separation standards that are related to the ADS capability to provide position and intent information to controllers and users. Other R,E&D goals are to develop a reliable digital air-ground communications system, to investigate flight deck/controller workload issues, and to monitor aircraft conformance to planned route of flight. In Phase 2 and Phase 3, the oceanic and en route domains will evolve toward a consistent, seamless operational environment.

10.1.9 Terminal

The research goals are to provide DSS and automation tools that help controllers establish optimal runway assignments and efficient arrival and departure paths. The tools will also support digital communications to the flight deck, implementation of reduced separation standards (commensurate with improved surveillance), and flight plan conformance monitoring. Automation tools will be integrated across facilities for consistency in optimizing traffic flow. Collectively, these tools will enable the number of departure and arrival paths to be increased and allow for more efficient arrival trajectories, including providing wake vortex spacing.

Tools will be developed to support data link transmission of altitude assignments, frequency changes, and certain clearances to aircraft. Research efforts will also investigate automated methods for controllers to coordinate gate and runway assignments with arriving aircraft in near real time.

Phase 1 research efforts will evaluate a streamlined method for designing and certifying arrival and departure routes. During Phase 2, research on integrating the automation decision support system to meet terminal and offshore requirements will determine the appropriate level and extent of integration. Information display techniques will then be developed to integrate surface, terminal, and wake vortex information into a simplified format to support departing and arriving traffic sequencing. Data link applications that support air-ground negotiation of arrival trajectories will be investigated. Phase 3 research on the integration of the automation decision support system to meet terminal and surface requirements will determine the appropriate level and extent of integration. Research efforts will also examine more effective means of displaying flight progress information and concepts for other backup modes of operation.

10.1.10 Tower

Tower-oriented research will provide decision support system tools and associated systems integrated with terminal automation tools. This research will support predeparture clearances by data link; real-time collaboration with terminal; dynamic planning of surface movement; better coordination of local operations based on arrival information and surface and departure schedules; surface and airborne surveillance information; and flight and weather information. This information will be provided to service providers, airline ramp operators, airport operators, and airport emergency center personnel.

10.1.11 Flight Services

The research goal in this domain is to develop decision support tools and associated systems for interactive preflight planning. The system will provide planners with information (such as NAS constraints, SUA status, and notices to airmen (NOTAMs)) and feedback about nonapproved segments of the proposed flight plan. The system will also propose alternatives so that a planner is able to select the optimum route. Capabilities improved by this research include interactive flight planning and reduction or restructuring of visual flight rules (VFR) flight plans (using the NAS-wide information service and the flight object).

The research will also investigate improvements to search and rescue capabilities using aircraft-transmitted ADS-B position and identification. Additionally, this capability will also incorporate data received from the newly developed ELT, which provides discrete identification codes and GPS-based position information (see Section 18, Avionics).

Phase 2 research efforts will enhance interactive flight planning and alternative route development decision support tools. It will also enhance search and rescue operation efficiency. Research will look at the design of compatible domestic and international flight plan/flight object formats to allow for increased preflight and in-flight information exchange among service providers and users.

Phase 3 research will develop the guidelines and specification for the detailed time-based trajectory flight profile that will replace the flight plan.

10.1.12 Aviation Weather

The aviation weather research program focuses on applied research and conducting limited basic research through collaboration with other federal and academic institutions. The program aims to generate more accurate and accessible weather observations, warnings, and forecasts that allow the FAA to solve operational problems. Research focuses on these areas:

In-Flight Icing. The goal is an hourly, gridded depiction or forecast of in-flight icing. Research on freezing drizzle and icing severity will continue.

Aviation Gridded Forecast System. This system mitigates communications bandwidth problems by transmitting the weather data as gridded data fields, which are smaller than large graphic files. Mesoscale models will use higher resolution grids and improved algorithms to provide refined, critical weather elements data—such as convection, icing, and turbulence—to the aircraft.

Weather Support to Deicing Decisionmaking (WSDDM). To optimize ground deicing operations, WSDDM software will produce an accurate graphical depiction of the real-time, 30-minute nowcast and a 4-hour forecast of precipitation intensity and type, weather condition, temperature, and wind speed for the 10-kilometer area around an airport.

Humidity and Turbulence. Sensors are installed on board commercial aircraft to obtain outside humidity data and algorithms that are added to the In-flight Management System to calculate turbulence. Humidity and turbulence data are then downlinked as part of the aircraft's normal air-ground communications. These increased and expanded data provide a new capability for National Weather Service (NWS) models, which improves forecasting. At the same time, these improved airborne data allow scientists to update the logic in the algorithms used in the weather processors. This data will be used to develop and test national-scale turbulence modeling efforts.

Convective Weather. Research is underway to improve convective weather forecasting to provide forecasts of storm cells. Forecasts range from short-term predictions of storm growth and decay (nowcasts) to longer-term predictions of convective storm activity. The goal is to improve today's forecasts from 30 minutes to 6 hours in advance.

Ceiling and Visibility. This research is aimed at providing short-term (up to 6 hours in advance) predictions of when the ceiling and/or visibility in a terminal area will allow routine instrument flight rules (IFR) operations to be resumed.

Model Development and Enhancement. This research effort focuses on improving the accuracy of numerical weather models that support aviation weather.

Wake Vortex. The primary objective of the FAA Wake Vortex program is to increase understanding of vortex behavior so that new wake vortex separation rules based on aircraft performance can be established to increase terminal capacity.

10.1.13 NAS-Wide Research, Engineering, and Development

Concept of operations (CONOPS) research is a cross-cutting activity that will be conducted to develop additional detail and to validate the CONOPS for the modernized NAS. Research will include identifying and validating task taxonomy, roles and responsibilities, information flows, and scenarios. Human-in-the-loop analyses of the scenarios associated with concepts that reassign tasks or roles and responsibilities will also be performed. Finally, fast-time simulations will be conducted to link human-in-the-loop results to NAS levels of traffic and complexity.

Evaluation and validation of the safety and environmental impacts associated with the CONOPS will be performed. The system modeling of the NAS and the CONOPS will be updated to improve operational performance analysis. This analysis will support all phases of operational and system development (i.e., concept development, concept validation, demonstration, and deployment). It will also significantly improve the economic assessment in the investment analysis process.

Research is required to support flexible airspace use and dynamic resectorization. Some factors that will be considered are use of analytic tools and development of performance measures for airspace utilization. Tools will be developed to evaluate airspace structure and sectorization during the day and to make adjustments as operational situations demand. Additional airspace considerations are to expand the oceanic and en route routing structures and make them flexible. In the terminal area, the goal is to expand the number of airport departure and arrival routes. Some research considerations are increased use of space-based navigation, late-descent flight profiles, and higher aircraft speeds when flying below 10,000 feet.

Research is required to establish operational infrastructure strategies based on availability and safety of services. The primary goal is to develop a fault-tolerant NAS design based on safety, risk, security, and economic analysis. Studies will be conducted to determine metrics for system safety and system performance parameters. Increased NAS automation will require studies to determine the proper level of information security.

A NAS software research and development program will investigate domain-specific software architecture to improve software reuse and reliability. The program will address software certification, especially safety-critical systems that use commercial off-the-shelf software.

The R,E&D program will further review the expanded use of remote monitoring and maintenance control that will include CDM for prioritizing preventive and restorative maintenance activities.

R,E&D activities are needed to support security services in the future NAS. This is associated with developing and implementing new hardware and software functionality and related processing and information flows. Known security approaches may not scale well, or they may not be appropriate for the NAS's mixed government-private composition. R,E&D security activities must also address the security impacts of planned NAS work and define the necessary enhancements.

An additional requirement for the modernized NAS is to research innovative methods to support investment decisionmaking by the FAA. Because of the deregulated nature and the diversity of the user community, the traditional investment method of cost-benefit analysis is becoming increasingly ineffective. A strategy that reduces uncertainty by considering the complex nature of the NAS and the service role of the FAA is needed. A major consideration is the cost-effectiveness of user avionics and the cost of the decision support systems required to support the CDM capability of the automated NAS infrastructure.

To contribute to the development and implementation of the 2005 NAS CONOPS and its supporting architecture, human factors research will be addressing issues implicit in the design of new systems and procedures. Research in this area will define changes to operational concepts, and human factors research will provide information concerning the feasibility of these operational changes.

The research and development activities regarding separation standards and assurance will contribute to safe separation of air traffic. The primary goal of separation standards research is to provide decisionmakers with quantitative guidance for establishing and maintaining safe separation standards. The secondary goal of this research is to provide decisionmakers with tools to assess the value of changing separation standards. Methodologies will be developed to determine minimum safe separation criteria. The process will account for the performance of situational awareness systems, such as navigation, communication, surveillance, and decision support systems. Additionally, operational factors such as traffic flows, ATC, and cockpit human factors will be accommodated, and uncontrollable influences such as weather and in-flight emergencies will have to be considered.

Research will consider the adaptation of international standards for reducing vertical separation to 1,000 feet between aircraft flying above 29,000 feet. Additional research will be needed to develop the requirements for transferring safe separation assurance responsibility from ATC to the cockpit under certain situations. The benefits and costs of reducing or changing separation standards also need to be assessed.

10.2 Airports Technology

The Airports Technology R,E&D mission is to provide solutions that will allow the nation's airports to accommodate the projected traffic growth cost-effectively and safely. See Section 11, Regulation and Certification Activities Affected by New NAS Architecture Capabilities, for more details.

Airport technology R,E&D programs develop new standards and criteria for airport planning, design, construction, operation, and maintenance. Research into visual guidance systems will enhance airport ground operations at night and during low-visibility conditions. Improvements in airport lighting, signs, and markings will help eliminate runway incursions. Airport research includes:

- Airport planning and design research, which produces aircraft/terminal compatibility analyses, design standards for terminals, design standards for multiple/parallel runways, and user guides for airport operators and industry
- Airport pavement technology research, which provides 3-dimensional, finite element models for airport pavement design, national pavement test machine, and data base of in situ airport pavement performance
- Airport safety technology research, which provides technical data supporting runway

maintenance regulations and advisory circulars; design specifications for fire training facilities; design criteria for airport, heliport, and vertiport lighting and markings; technical data on firefighting agents and vehicles; and technical data and advisory circulars on wildlife habitat management, bird harassment techniques, and landfills.

10.3 Aircraft Safety

R,E&D includes research in a wide range of areas related to the safety of aircraft, crew, and passengers. The R,E&D program develops technology, technical information, tools, standards, and practices to ensure the safe operation of the civil aircraft fleet within a safe global air transportation system. The program focuses on eliminating hazards to a safe air transportation system, both to prevent accidents and to mitigate the effects of any accidents that do occur. See Section 32, FAA Regulatory Mission, for more details.

Aircraft safety R,E&D programs develop new technologies to improve NAS safety and provide the FAA's Regulation and Certification organization (AVR) with the necessary information to carry out its mission. These programs address the many hazards that face all aircraft, as well as special hazards endemic to certain segments of the civil aircraft fleet. For example, older aircraft are susceptible to structural problems caused by metal fatigue and corrosion; newer aircraft, with digital flight controls and imbedded software, are susceptible to electromagnetic interference. The major aircraft safety programs include:

- Aviation safety risk analysis, which has resulted in the safety performance analysis system and the system for identifying aircraft certification risks
- Fire research and safety, which has led to requirements for non-halon fire-extinguishing agents, fire-hardened fuselage structures, fire-safe emergency oxygen systems, fire-resistant materials for cabin interiors, and cabin safety/benefit analysis models
- Advanced material/structure safety research, which is responsible for the handbooks on composite technologies and manufacturing/inspection analysis techniques, data packages on certification of structures made from advanced materials and on seat restraint systems, and technical data on crash-resistant auxiliary fuel system designs
- Propulsion and fuel systems work that has resulted in probabilistic engine rotor design code, specifications for titanium alloys, and certification standards for unleaded fuels
- Flight safety/atmospheric hazards research that led to aircraft surface-ice detection technologies and systems, electronic threat definition and validation, and technical data on digital technology for flight-critical systems
- Aging aircraft program work that has enabled the development of analytical tools and models to assess commuter and transport aircraft structural integrity and repairs.

Human factors research is used to improve:

- Systems design
- Certification and regulation decisions
- Operating directives
- Training procedures.

Human performance remains a critical part of safe and efficient NAS operations. Advances in technology have increased the reliability of most NAS components; however, the number of accidents and incidents attributed to human error has remained constant. AVR's human factors programs support the National Plan for Civil Aviation Human Factors by addressing priority areas such as aircrew performance, aircraft maintenance, and aircraft cabin environment. Human factors research includes:

- Research into the flight deck and aircraft maintenance areas that led to the development of human factors guidelines to reduce automation-related errors
- Flight deck/ATC system integration work that resulted in human factors guidelines for computer-human interface applications and the ability to assess human performance in a highly integrated/automated environment
- Aeromedical research that led to quantitative bioengineering criteria for aircraft evacuation, flotation devices, and other rescue equipment.

10.4 Human Factors and Aviation Medicine

The Human Factors and Aviation Medicine program identifies methods that help reduce the fatal accident rate; ensures human factors issues are addressed in the acquisition and integration of FAA aviation systems; and develops recommendations for protective equipment, procedures, standards, and regulations to protect all aircraft cabin occupants. Human factors research will increase NAS safety and efficiency by developing scientifically validated information and guidance for improving the performance and productivity of air traffic controllers and NAS system maintenance technicians. The Human Factors program addresses operational requirements through research in the areas of Human-Centered Automation, Selection and Training, Human Performance Assessment, Information Management and Display, and Bioaeronautics. For more details, see Sections 8, 15 through 27, and 32.

10.5 Aviation Physical Security

The main goal of the Aviation Security program is to mitigate the terrorist threat to the civil aviation system. Through the Aviation Security R,E&D program, the FAA promotes development of technologically improved products in explosive detection, aircraft hardening, airport security, and human factors. Products from the R,E&D program include explosive detection systems and devices, technologies, specifications, and technology integration plans. See Section 32 for more details.

Civil aviation security is focused on countering increasingly sophisticated threats to civil aviation. The spread of terrorism makes it imperative that the FAA develop effective countermeasures. Emphasis is on developing automated capabilities to prevent explosives from being carried onto aircraft and on enhancing human performance. Research also includes devising test protocols and performance criteria for automated explosives detection systems. Civil aviation research includes:

- Explosives/weapons detection research that has developed trace and bulk personnel screening portals and certification of trace electronics screening systems
- Aircraft hardening research that provides guidelines for blast mitigation/aircraft hardening, design specifications for aircraft and support equipment, and threat assessments on advanced terrorist weapons
- Airport security technology research that provides airport vulnerability reports and analytic models for threat, risk, and vulnerability assessment
- Aviation security human factors research that produces human systems integration analyses, reports on explosives and weapons detection technologies, and automated profiling systems.

10.6 Environment and Energy

The Environment and Energy R,E&D program identifies, controls, and mitigates environmental consequences of aviation activity. The program is composed of three major disciplines, including aircraft noise reduction and control, engine emissions reduction and control, and aviation environmental analysis. These disciplines form a cohesive focus of research projects to support federal actions regarding noise and engine exhaust emissions. See Section 30 for more details.

10.7 Program Management

The Program Management R,E&D program provides for effective and responsible stewardship of funds entrusted to the FAA for research and development by NAS users. Effective stewardship of the R,E&D program requires that NAS users receive the best possible program for their investment. Participants ensure that the correct research is performed, the necessary provisions are made in the budget and planning process, and the highest standards of financial accountability are rigorously maintained.

Additionally, the program must fund no research that duplicates work being performed elsewhere, particularly with National Aeronautical and Space Administration (NASA) funding. The FAA has and will continue to work with other agencies, including NASA and DOD, to leverage research dollars in the search for common solutions to problems affecting aviation.

10.8 Summary

Understanding what role new and emerging technologies play in NAS modernization and how to best adapt these technologies to increase NAS efficiency and safety are key elements in implementing this architecture. Working with industry and other government agencies, the FAA will leverage scarce resources to maximize potential benefits.

The transition of research funding from R,E&D to F&E appropriations has created a direct linkage between research and capital investment. Much of the research identified in the *National Airspace Architecture Version 4.0* will need to rely on funding by public/private partnerships, industry investment, and the developing consensus on the role and funding level for research within the FAA and NASA on aviation research.

11 REGULATION AND CERTIFICATION ACTIVITIES AFFECTED BY NEW NAS ARCHITECTURE CAPABILITIES

The FAA's regulation and certification mission is carried out primarily by the Regulation and Certification (AVR) organization. AVR is responsible for aircraft and aircraft component certification, continued airworthiness monitoring and inspection, and new or revised flight regulations that change operating procedures. The other FAA organizations that perform regulation and certification activities related to their primary mission are Air Traffic Services (ATS) and Research and Acquisitions (ARA).

ATS is responsible for ground-based equipment acceptance and certification. It also revises controller operational procedures and orders as necessary to achieve the full benefits of the modernization effort. Most ground-based systems described in the NAS architecture will have an ATS acceptance and certification requirement.

ARA develops initial functional and performance specifications for products with the sponsoring organization during the Integrated Product Team process. If the system produces electromagnetic signals, the Office of Spectrum Policy and Management (ASR) develops additional performance specifications, such as what portion of the radio frequency spectrum the system will use and parameters for radio frequency interference protection. Prior to system implementation, ARA conducts initial evaluations to ensure products meet requirements.

For NAS architecture purposes, the FAA's regulation and certification activities can be divided into three broad categories: ground-based components, airborne components, and procedures/rulemaking. However, certification processes may vary on a case-by-case basis. That is, each product has a unique set of variables that affect the length of the certification process. Following is a high-level discussion of the complex, cross-organizational certification mechanisms required by the FAA.

11.1 Ground-Based Components

Most of Part III, NAS Architecture Description, addresses ground-based air traffic control systems that the FAA will acquire as part of NAS modernization. The organizations responsible for ground-based equipment acceptance and certification are determined by the equipment's function and intended use. Some systems may require acceptance and certification from both the Airway Facilities Service (AAF) and Air Traffic Service (AAT);[1] others may require action by only one. For example, the Host/Oceanic Computer System Replacement (HOCSR) described in Sections 21, En Route, and 22, Oceanic and Offshore, will require AAF acceptance and certification for initial operating capability (IOC) based on specific parameters developed for this equipment. Typically, one formal parameter to declare IOC involves having technicians properly trained in system maintenance. Transition from IOC to operational readiness demonstration (ORD) is the responsibility of AAT.

The transition to ORD typically involves a period of dual operation of the old and new systems so that personnel can gain confidence and operational experience with the new equipment. Although the HOCSR, for example, probably will not require any specific controller training, training for other infrastructure systems is an important requirement that must be satisfied before the transition to ORD can begin. ATS will also be responsible for any changes to procedures enabled or required by the new system (see paragraph 11.3, Procedures/Rulemaking, for further discussion).

11.2 Aircraft Components

Many of the new capabilities and modernization efforts described in the NAS Architecture Version 4.0 depend on equipping aircraft with certified avionics. AVR is responsible for all airborne certification and procedural regulatory activities. Within AVR, the Aircraft Certification Service staff is responsible for certification related to de-

1. The Airway Facilities Service (AAF) and Air Traffic Service (AAT) are sub-organizations within the Air Traffic Services (ATS) organization.

PART II

sign, production, and installation approvals for aircraft, aircraft modifications, and aircraft appliances as well as for monitoring manufacturers after approvals are issued. Specialists in aircraft certification offices (ACOs) located throughout the United States perform certification approval and manufacturer monitoring. The applicants are ultimately responsible for demonstrating to the FAA ACO representatives that their designs comply with all applicable federal regulations. In general, certification processes lead to the same three required approvals: design approval, production approval, and installation approval.

Several methods are used to certify aircraft equipment such as avionics, but these methods only apply to aircraft that have Type Certificates. Avionics can be certified through an Amended Type Certificate, Parts Manufacturer Approval, Technical Standard Order Authorization, Supplemental Type Certificate, Form 337 Field Approval, or approval under an Operating Certificate (the airline equivalent of a Form 337 Field Approval).

Certificated aircraft have a Type Certificate and Production Certificate based on the approved type design drawings and specifications that define the configuration and design features of the product, including avionics equipment. For new avionics, the Type Certificate holder may elect to follow a process that amends the Type Certificate and Production Certificate to gain the design, production, and installation approvals for that aircraft model. The extent of the change determines how simple or complex the amendment process needs to be.

The Parts Manufacturer Approval and Technical Standard Order Authorization processes give manufacturers design and production approvals for their products, but do not provide an installation approval. The installation approval is subsequently granted through a Supplemental Type Certificate, Form 337 Field Approval, or under an Airline Operating Certificate.

The difference between a Parts Manufacturer Approval and Technical Standard Order Authorization is the certification basis. A Parts Manufacturer Approval is granted based on test reports and computations conducted under an FAA-approved and -supervised test plan; identicality with a previously certified article; or a licensing agreement from a Type Certificate or Supplemental Type Certificate holder. For a Technical Standard Order Authorization, the FAA establishes minimum performance standards for the general equipment item (i.e., radios, the Global Positioning System (GPS), transponders, etc.), and the applicant submits material for FAA review demonstrating that their product meets the standards.

The Supplemental Type Certificate process is used to grant any one or all three required certification approvals (design, production, installation) for changes to a Type Certificated product. A Supplemental Type Certificate (STC) is only valid for a specific aircraft (one-time STC) or a specific aircraft make and model (multiple STC). To receive an STC, applicants must provide data proving the Type Certificated product still complies with its applicable certification basis. The complexity of the STC process depends on the extent of the change being requested.

The Form 337 Field Approval process typically involves a Flight Standards Service representative[2] certifying that the alteration complies with regulations and conforms with accepted industry practices. The three elements of this process are approval of data, conformity of installation, and approval to return the aircraft to service. Approval can be accomplished through an engineering review, by physical inspection and testing, or by demonstration. Field Approvals usually apply to one specific aircraft and require relatively less design data for substantiation than the other certification processes. The extent of the alteration determines if the Field Approval process can be used or if one of the other certification processes is needed.

11.3 Procedures/Rulemaking

NAS operations are governed by a complex set of procedures and rules that determine controller and pilot actions. The new equipment and concepts described in this document will have little or no effect on the NAS until both controllers and pilots have approved procedures that enable a change in operations. In some cases, the NAS architecture

2. The Flight Standards personnel may receive support from Aircraft Certification Service engineers or manufacturing inspectors if needed.

will also require airspace structure revisions before the projected benefits can be realized.

11.3.1 Controllers

ATS develops controller procedures for ground-based air traffic control (ATC) components of NAS modernization. FAA Order 7110.65, Air Traffic Control, describes services provided by controllers, safety standards that must be maintained, and standardized methods to accomplish controller tasks. However, many of the new concepts, such as Free Flight, fall outside the current boundaries of 7110.65. If no changes are made to procedures, controllers will be limited to using the new equipment for traffic separation in much the same way they used the equipment that was replaced. This could severely limit the benefits from modernization efforts and prevent final implementation of new concepts such as Free Flight.

ATS is also responsible for airspace redesign. Today, changes to airspace design are usually done at the local level by the air traffic facilities that require a change. Typically, only refinements that do not drastically alter the airspace configuration around the facility are made to the existing structure. However, new capabilities for air traffic control proposed in the architecture may require strategic, systemwide changes to the airspace structure.

Without new controller procedures and changes to the current airspace structure, new NAS capabilities will not be fully exploited, and the intended benefits will not be realized. Future versions of the architecture will need to address in greater detail how, when, and what changes to controller procedures and airspace design are needed for the future NAS as part of a fully integrated modernization plan.

11.3.2 Pilots

The Flight Standards Service develops basic operating procedures for pilots established in selected parts of 14 Code of Federal Regulations (CFR). Airlines may supplement these regulations with FAA-approved company operating procedures. Many new capabilities will require new avionics in aircraft before benefits are realized. Accordingly, regulations will need to be revised or new regulations created so that pilots can use new avionics fully.

Table 11-1 is a preliminary summary of current regulations in 14 CFR, Parts 1 through 1273, that are affected by the baseline architecture capabilities. The preliminary assessment has identified 11 regulations that will require modification. Full descriptions of the capabilities listed in Table 11-1 appear in Section 5, Evolution of NAS Capabilities, and Appendix D, NAS Capabilities and Matrix.

For systems implemented in the near term, affected regulations will generally require only modest wording changes. However, in many instances, the existing regulations do not address the new capabilities described in the architecture, such as direct routing or cockpit display of traffic information for air-to-air surveillance. Therefore, new regulations will be required before longer-term concepts and systems can be implemented. In particular, the existing regulations will have to be expanded, or new regulations written, to establish minimum avionics equipage requirements relative to airspace class[3] and type of operation.[4] Additionally, procedures will have to be established for both controllers and pilots that detail how aircraft with varying equipage levels will be accommodated when operating in the same airspace.

Creating or changing regulations is a complex, time-consuming process. By law, there are sequential steps and mandatory comment periods that must be observed before a rule becomes final. Simple changes or rules that do not generate a great deal of comments can be processed in 12 to 18 months. However, it can take 3 to 4 years for a final rule to be issued if it entails major changes that generate many comments from the aviation community. It is reasonable to assume that any rulemaking actions resulting in significant operational changes or minimum equipage requirements will generate intense interest from the aviation community.

3. Refers to class A,B,C,D,E, and G airspace.
4. Visual flight rules, instrument flight rules, 14 CFR Part 91, 121, 135, etc.

PART II

11.4 Summary

The full range of benefits projected by the NAS architecture will not occur without new or revised aircraft operating regulations with complementary controller procedural changes and airspace redesign. These are complex issues that will be addressed in the architecture through a cooperative effort of the FAA and the aviation community.

Table 11-1. Preliminary Analysis of Regulations Affected by the Baseline Architecture (Sheet 1 of 2)

Capability Title	Federal Aviation Regulation (FAR) Part									
	1.1	1.2	61.63	71.75	71.901	91.205	121.349	129.17	147 Appendix C	170.3	171 new Subpart K
Initial WAAS Precision Approach Existing Airports	X	X	X	X	X	X	X	X	X	X	X
WAAS Precision Approach New Qualifiers	X	X	X	X	X	X	X	X	X	X	X
GPS Oceanic	X	X		X	X	X	X	X	X	X	
Terrain Avoidance	X	X				X			X		
Initial WAAS Cruise	X	X	X			X	X	X	X	X	X
LAAS Cat I	X	X	X	X	X	X	X	X	X	X	X
LAAS/Cat II/III	X	X	X	X	X	X	X	X	X	X	X
ITWS Stand Alone	X	X				X			X		
Initial TWIP	X	X				X			X		
Expanded TWIP	X	X				X			X		
MDCRS	X	X				X	X	X	X	X	
Enhanced MDCRS	X	X				X	X	X	X	X	
Initial FIS	X	X				X			X		
Automatic Simultaneous Weather Notification	X	X				X			X		
Improved Terminal Surveillance (ASTERISK/SI)	X	X				X			X		
Runway Incursion Reduction	X	X				X		X	X		
Integrated Terminal Surveillance with ADS-B	X	X				X	X	X	X	X	
Integrated En-Route Surveillance with ADS-B	X	X				X	X	X	X	X	
Improved En-Route Surveillance (ASTERISK/SI)	X	X				X	X	X	X	X	
Integrated Tower Area Surveillance	X	X				X	X	X	X	X	X
Air-Air ADS-B	X	X				X	X	X	X	X	X
TIS via Mode-S	X	X				X			X		
ADS-B Gap Filler	X	X				X			X		
Ocean Surveillance via ADS-A	X	X				X	X	X	X	X	X
TDLS	X	X				X			X		
CPDLC Build 1	X	X				X			X		

Table 11-1. Preliminary Analysis of Regulations Affected by the Baseline Architecture (Sheet 2 of 2)

Capability Title	Federal Aviation Regulation (FAR) Part									
	1.1	1.2	61.63	71.75	71.901	91.205	121.349	129.17	147 Appendix C	170.3	171 new Subpart K
CPDLC Build 1A	X	X				X			X		
Oceanic Data Link	X	X				X	X	X	X		
Multi-Sector Oceanic Data Link	X	X				X	X	X	X		
Expanded TDLS	X	X				X			X		
CPDLC Build 2 via VDL Mode-2	X	X				X		X	X	X	
CPDLC Build 2 via VDL Mode-3	X	X				X		X	X	X	
CPDLC Build 3 via VDL Mode-3	X	X				X		X	X	X	
NAS-Wide Data Link	X	X				X		X	X	X	
Interactive Airborne Refile	X	X				X		X	X	X	
aFAST with Wake Vortex	X	X				X		X	X		
RVSM/50 Lateral	X	X				X	X	X	X	X	
50/50	X	X				X	X	X	X	X	
SMS	X	X				X		X	X		
Low-Altitude Direct Routes—Using WAAS	X	X	X	X	X	X	X	X	X	X	X
Low-Altitude Direct Routes—Expanded Radar Coverage	X	X	X	X	X	X	X	X	X	X	X
Low-Altitude Direct Routes—Expanded Surveillance Coverage	X	X	X	X	X	X	X	X	X	X	X
NAS-Wide Information Sharing	X	X				X		X	X		
ELT for SAR and Flight Following	X	X				X		X	X		

12 PERSONNEL

As in most major service organizations, people are the NAS's greatest asset. Thousands of people operate the equipment used to provide NAS services to the aviators and passengers each day. The FAA employs over 47,000 people. FAA operations personnel include 17,000 operational controllers, 3,500 flight service personnel, and 8,000 maintenance personnel located at NAS sites throughout the United States. The user group includes 650,000 pilots operating more than 280,000 commercial, regional, general aviation, and military aircraft, and 2,000 manufacturers.

FAA personnel include air traffic controllers, operational controllers, flight service specialists, maintenance engineers, safety and security inspectors, environmental specialists, systems and software engineers, operations research analysts, human factors specialists, business managers, and scientists, as well as individuals skilled in a number of other disciplines.

These personnel are located at the FAA Headquarters in Washington, D.C., FAA towers, FAA air route traffic control centers (ARTCCs), and flight service stations. Air Traffic Services, which provides the majority of FAA personnel, is comprised of Air Traffic (AT), Airway Facilities (AF), Air Traffic System Requirements, System Capacity, and Independent Operational Test and Evaluation.

12.1 Factors Affecting Staffing Levels

Three primary factors affect staffing levels and costs assumed in the architecture: anticipated growth in air traffic operations, union contracts, and deployment of the NAS infrastructure management (NIM). A discussion of the effects of these changes follows.

Traffic Growth

According to FAA forecasts, worldwide aviation growth tracks with economic growth. Passenger traffic, domestic enplanements, and international enplanements are forecast to increase annually. Aircraft operations are forecast to grow at a rate of 2.0 percent per year from 1994 to 2006.[1] The growth is assumed to continue at the same rate from 2007 to 2015. Consistent with the AT staffing plan projections, center and tower/TRACON controller staffing levels will increase at a rate of 0.75 percent per year from 2003 through 2015.

As the NAS modernizes, workforce requirements and changes will need to be incorporated with a long-term view. The NAS Sustainability Core Team determined that greater efficiencies and required skill sets will be sought by users and Congress that are not in place today. Staffing knowledge, skills, and abilities of the future workforce will change as major programs are implemented. Airway Facilities positions will require increased knowledge of computer systems, software applications, air traffic operations, and NAS service management, as well as satellite and digital technology. Although no significant changes are needed in major functions performed, staffing, training, and hiring required to support mission needs should be identified early.

Union Contracts

The new labor agreement recently reached with the National Air Traffic Controllers Association (NATCA) includes a reclassification of air traffic control (ATC) facilities from 5 categories to 12. The effects of this reclassification on the total number of controllers required and their associated costs have not been considered for this architecture. *Contract negotiations are currently underway with the Professional Airways Systems Specialists (PASS). Any changes to staffing levels or costs are not included in this version of the architecture.*

NAS Infrastructure Management (NIM)

NIM is a centralized management concept for the NAS infrastructure, with maintenance control centers distributed throughout the country. Transitioning to operations control centers (OCCs), implementation of remote maintenance monitoring capability, and changes in the maintenance philosophy will improve performance. The envisioned maintenance philosophy calls for deleting the incumbent contractor maintenance and implementing in-house field and software maintenance.

1. Source: *Federal Aviation Forecasts*, Fiscal Years 1997–2008.

PART II

NIM tools deployment will result in part of the AF workforce (personnel who are not directly assigned to systems) remaining constant. Initial staffing reductions have occurred in anticipation of NIM tools deployment. Immediate effects will apply to field maintenance specialists, computer operators, and the Operational Support Service (AOS) workforce.

12.2 Assumptions

Personnel Costs

The personnel funding in this section includes personnel salaries and benefits. Other related expenses associated with personnel—such as rent, utilities, travel, training, and change-of-station funding—appear in Section 31, Mission Support. Funding for system field specialists is included in the systems' Operations (OPS) funding lines.

The yearly expense for each person on the FAA payroll is projected to grow faster than inflation. Based on past trends, the expense of a controller grows at 3 percent per year above inflation, and the expense of non-controller workforce personnel grows at 1.5 percent per year above inflation. This growth, when compounded annually, causes considerable growth in OPS funding requirements.

Personnel Categories and Costs

Personnel funding is appropriated for the following categories under Research, Engineering, and Development (R,E&D), Facilities and Equipment (F&E), and OPS:

R,E&D

- *Personnel, Compensation, Benefits, and Travel (PCB&T, R,E&D):* Includes all personnel paid by R,E&D funding.

F&E

- *Personnel, Compensation, Benefits, and Travel (PCB&T, F&E)*: Includes FAA Headquarters acquisition personnel and airway facilities installation staff paid by F&E funding.

OPS

- *Air Route Traffic Control Center Personnel (ARTCC-P)*: Includes the controller workforce at air route traffic control centers (ARTCCs). These individuals guide and direct the aircraft traffic from gate to airport surface, takeoff, and landing and flight within 40 miles of airports.

- *Airport Traffic Control Tower Personnel (ATCT-P)*: Includes the controller workforce at air traffic control towers (ATCTs) and terminal radar control (TRACON) facilities.

- *Air Traffic Planning, Development, and Evaluation Personnel (PDE-P)*: Includes non-controller workforce air traffic personnel located at FAA Headquarters and in centers, towers, and terminal radar approach control (TRACON) facilities who perform the following functions: planning, directing and evaluating; administration; and system capacity analysis.

- *Flight Service Station Personnel (FSS-P)*: Includes flight service personnel. These individuals provide preflight and in-flight weather information for millions of general aviation flights in addition to filing the flight plans for those flights. Further, flight service personnel help customs activities with aviation border crossings and preliminary support for search and rescue for potentially downed aircraft.

- *FAA Headquarters Personnel (FAAHQ-P)*: Includes staff who perform the following functions: aviation regulation and certification, security, safety, acquisition, commercial space applications, airport administration, general administration, medical, and general counsel.

- *FAA Logistics, Flight Inspection Personnel (FAALFI-P)*: Includes flight inspectors and logistics personnel.

- *Airway Facilities Non-System (Non- Sys)*: Includes Airway Facilities Headquarters staff and regional and other staff not assigned directly to systems.

- *System Level Maintenance Workforce*: This level of personnel for specific systems maintenance is in the OPS and is not identified as a separate category in this section. Approximately 20 percent of the current FAA workforce maintains the ATC system.

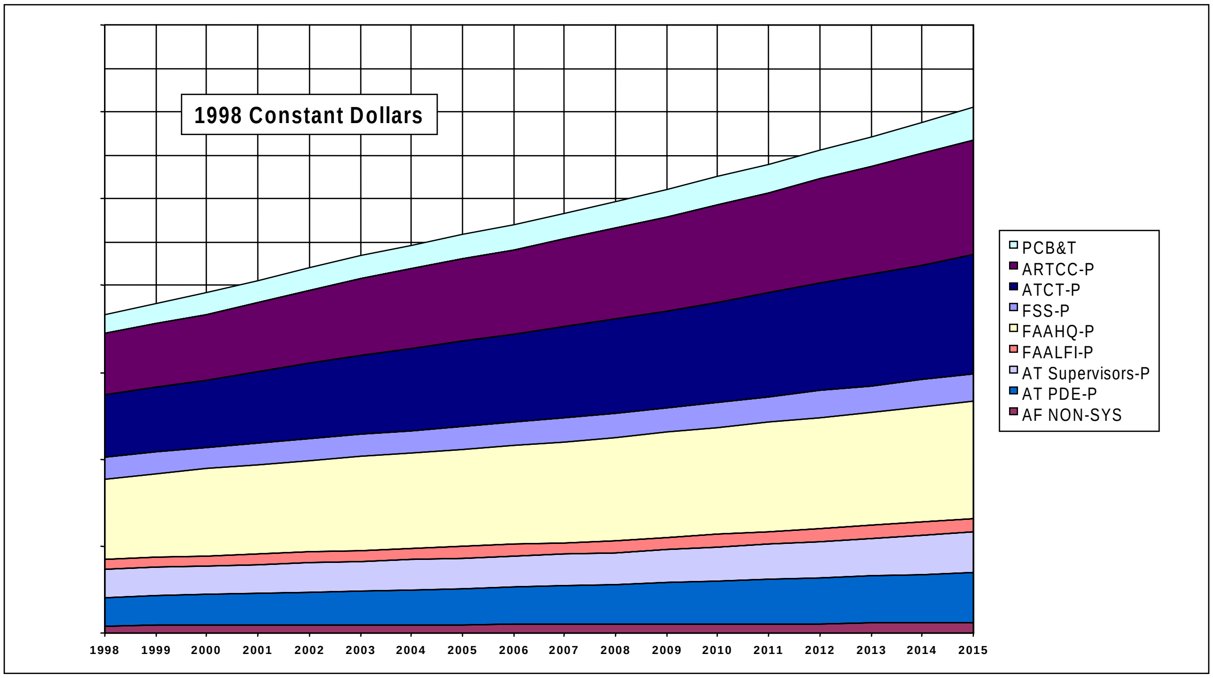


Figure 12-1. Estimated Personnel Costs

Staffing Levels

Figure 12-1 shows total personnel costs for both F&E and OPS by fiscal year, except for the AF systems field specialists whose positions are dedicated to maintaining specific systems. (The funding for those positions is included with OPS funding for the specific systems they support.) Total personnel costs forecast for 2015 are 30 percent higher than in 1998.

12.3 Watch Items

The effects of the labor agreement with the National Air Traffic Controllers Association (NATCA) in late 1998 reclassified air traffic control facilities. Contract negotiations with PASS have not been factored into this architecture.

12.4 Summary

As the architecture is implemented, the types and numbers of personnel required to operate and maintain the NAS should be reviewed and adjusted as necessary. Investigation into potential cost saving due to FAA staffing level reductions continues.

13 COST OVERVIEW

Costs for executing this architecture are based on full life-cycle costs for fielding, operating, and/or maintaining current systems and projected costs, including acquisition for future systems. NAS modernization costs include training, procedures development, regulation changes, and certification requirements. The funding levels described in the NAS Architecture Version 4.0 ensure continued safety for the flying public and growth of system capacity. Total costs by funding category are provided, except for Airport Improvement Program (AIP) funds, which are not currently integrated into the NAS architecture.

The primary cost is for air traffic management services (i.e., the process of efficiently clearing aircraft from origin to destination while maintaining safety). Other costs include:

- Safety:
  - – Safety inspection of aircraft
  - – Certifying new aircraft and avionics
  - – Testing and certifying pilots
- Capacity:
  - – Disseminating information to airspace users
  - – Maintaining the NAS infrastructure
  - – Introducing new technologies
  - – Strategic planning for future operations
- Security:
  - – Maintaining security at airports and FAA facilities and in flight
- Environment:
  - – Responding to environmental issues.

All costs represented in this document indicate fiscal year (FY) costs from 1998 through 2015.

13.1 FAA Funding Appropriations

The FAA receives four different types of appropriations from Congress each year: Research, Engineering, and Development (R,E&D); Facilities and Equipment (F&E); Operations (OPS), and AIP. Figure 13-1 shows total FY R,E&D, F&E, and OPS costs (escalated for inflation) associated with the architecture, which are based on the FAA's January 1998 funding projections through 2015.

13.1.1 Research, Engineering, and Development Funding

R,E&D activities minimize the risks associated with capital expenditures; focus research in areas with a high potential for success, such as joint re-

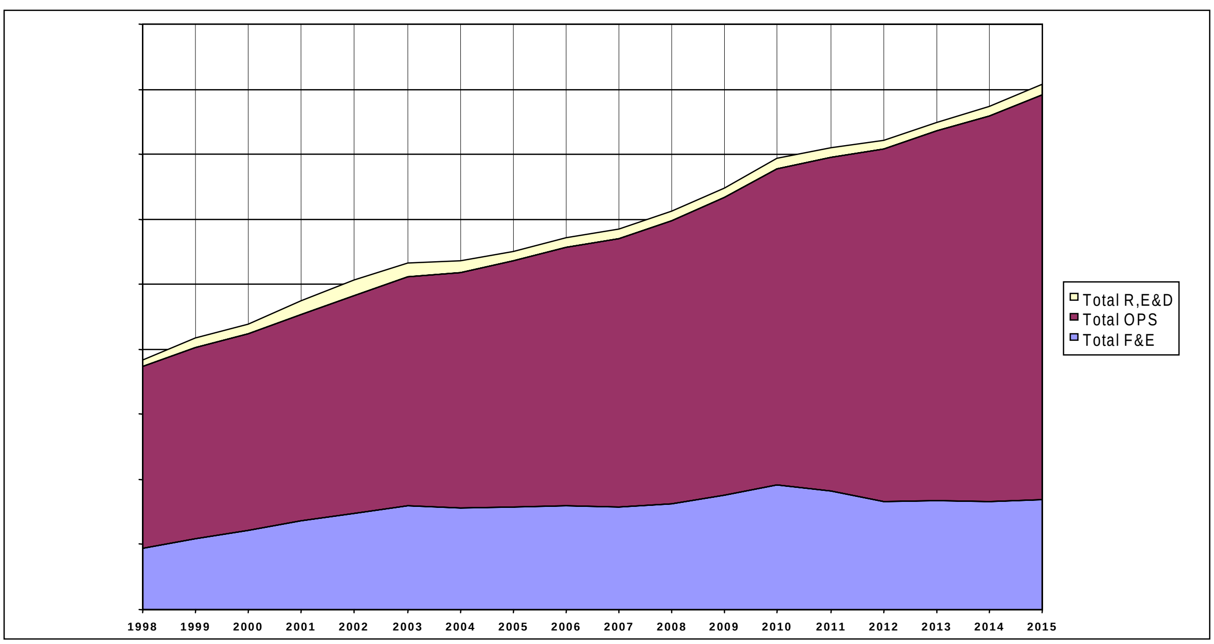


Figure 13-1. Estimated NAS Architecture Costs

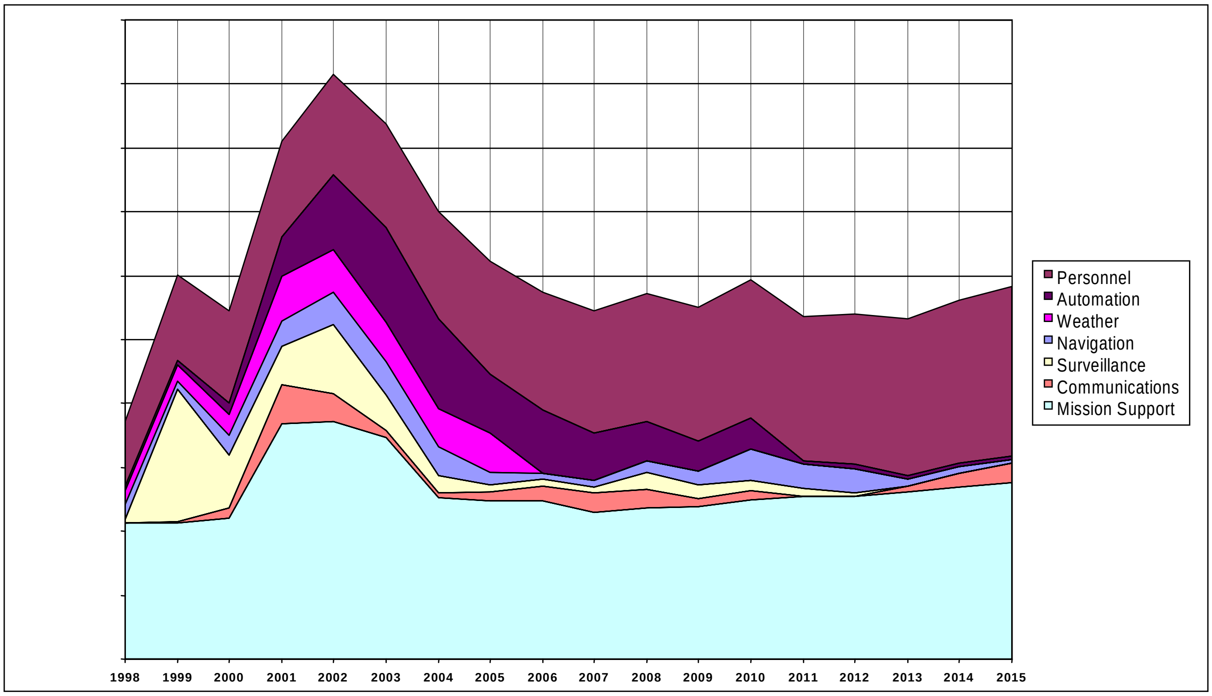


Figure 13-2. Estimated R,E&D Costs

search with the National Aeronautics and Space Administration (NASA) for future avionics; and research aviation-unique disciplines (e.g., aircraft fire safety). Figure 13-2 shows the estimated R,E&D funding requirements associated with the architecture. The FAA and NASA sponsor joint research projects; however, NASA research funding is not included in Figure 13-2.

The R,E&D funds required in the early years of NAS modernization (from 1999 through 2004) are significant because implementing a smooth, low-risk NAS transition depends on research. This R,E&D provides the foundation for projects that will implement the Government/Industry concept of operations (CONOPS). For more detailed information about R,E&D activities, see Section 10, Research, Engineering, and Development.

13.1.2 Facilities and Equipment Funding

Figure 13-3 shows the minimum estimated F&E funding required to implement the NAS architecture. F&E required in the financial baseline (from 1999 through 2004) is vital because a significant amount of equipment replacement and infrastructure refurbishment has been delayed due to the previous lack of funds. The FAA must modernize, repair, and replace a significant portion of its infrastructure in the near future to sustain current services and also to provide new capabilities and services to meet user needs. Delaying infrastructure replacement will cause increases in the OPS funding for maintaining equipment. Historically, systems reaching the end of their economic service lives fail more often and require increased maintenance. In addition, it is difficult, costly, and sometimes impossible to add functional enhancements to these older systems.

The gradual increase in F&E funding is shown in Figure 13-1. Additional future user needs will also emerge over time, which could increase funding requirements.

13.1.3 Operations Funding

OPS funding and estimated requirements are shown in Figure 13-4. Investing capital can save operating expenses. The architecture considers this, but as new systems are deployed, the total OPS cost for a service increases until its transition period is complete, the older equipment is removed from service, and the site is environmentally restored. This is most dramatically demonstrated in the navigation functional area with the deployment of the augmentation systems for satellite-based navigation and landing and the gradual phase-down of the ground-based navigation

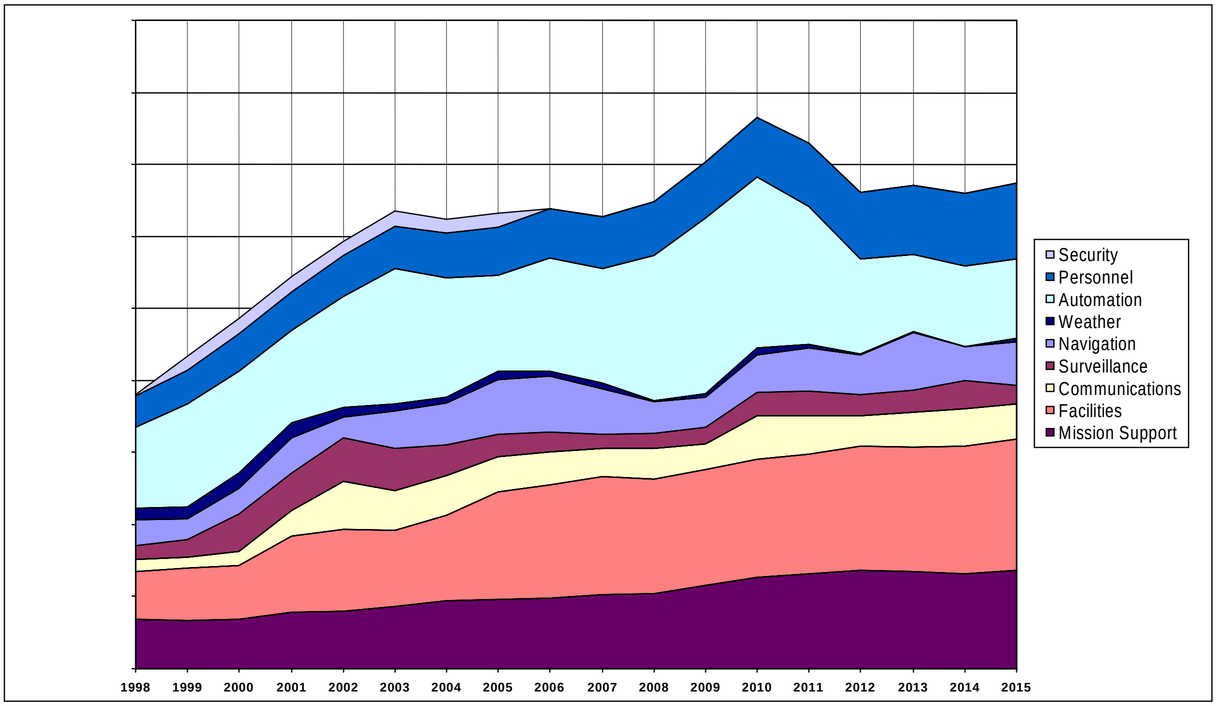


Figure 13-3. Estimated Architecture F&E Costs

and landing systems (see Section 15, Navigation, Landing, and Lighting Systems).

To implement the concepts of Free Flight, the FAA must increase the services it provides to NAS users. This is best demonstrated in the expansion of communications and information-sharing activities. Even though unit prices for communications and commercially available computer processors (like desktop personal computers) are decreasing, the FAA's use of and reliance

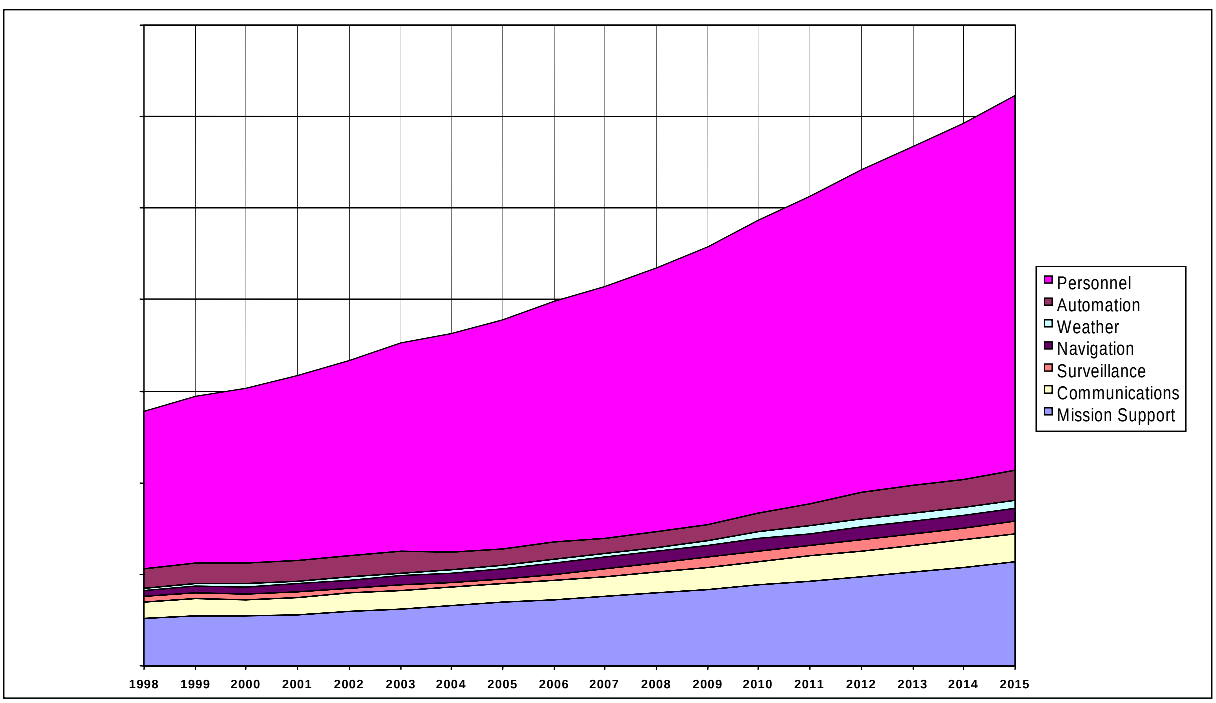


Figure 13-4. Estimated Architecture OPS Costs

on these items is increasing, and therefore, the total OPS cost to provide services will rise.

Operating the NAS is personnel-intensive; therefore, the dominating cost element is personnel cost (see Figure 13-5). Personnel account for approximately 70 percent of operations costs (see Section 12, Personnel). As traffic and services increase more FAA personnel (controllers, traffic managers, technicians, inspectors, etc.) may be needed.

13.1.4 Airport Improvement Program Funding

AIP funds are primarily airport improvement grants given to various qualifying airports. Airports use the money to help modify or add runways, relocate utilities, or even buy land around the airport to ensure environmental compliance for noise restrictions. Currently, AIP funding is not included in the architecture cost profiles. In FY99, work will focus on integrating airport development needs into the architecture. See Section 28, Airports, for additional information. The FAA will continue to fund approach lighting and landing aids based on current criteria.

13.2 User Avionics Costs

For NAS modernization to be realized, aircraft need to equip with new avionics. The costs for avionics required by NAS modernization, as well as the transition/implementation periods, have been estimated. The estimates were developed by the FAA working in conjunction with avionics manufacturers, aircraft manufacturers, airlines, and general aviation organizations. These costs are discussed in Section 18, Avionics.

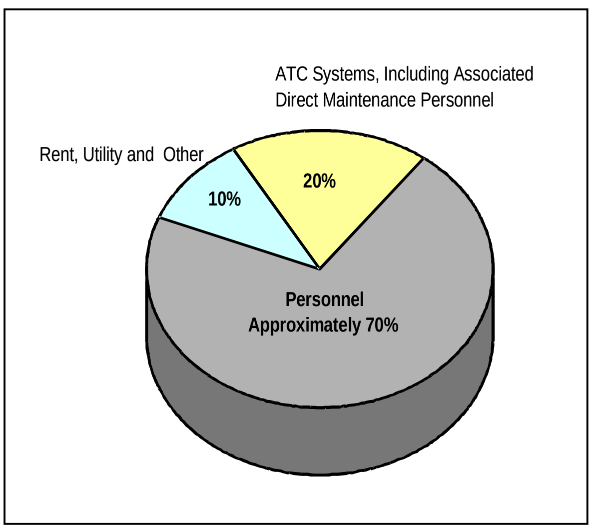


Figure 13-5. Estimated OPS Costs

13.3 Cost Estimate Methodology

Consistent with funding, a key goal of the NAS architecture is to modernize the NAS as quickly as possible to achieve Free Flight. In the architecture, investments are planned for new technology to implement Free Flight capabilities. Aging facilities and equipment are replaced in a time-phased manner. Capital investment is promoted to avoid escalating maintenance costs.

Most systems in the architecture are life-cycle funded. Life-cycle cost estimates include research and development; procurement; installation; operations; associated personnel costs; and technology updates and other system upgrades. The timing of funding for new systems and upgrades to existing systems is based on the estimated life cycles of existing systems and on the estimated refresh cycle of the associated replacement systems.

Some individual projects or investment areas (e.g., traffic flow management and communications) may show spikes of funding in some years. These numbers can be smoothed by using multiyear funding. As the budgeting process is completed, the estimates are revised to stabilize the yearly funding requirements.

Cost estimates are based on a variety of sources, including:

- Engineering judgment
- Industry estimates
- Investment analyses
- Cost-benefit analyses (CBAs)
- Life-cycle cost estimates prepared to support mission analyses
- April 1997 Future Telecommunications Book for communications OPS costs
- Cost Performance System (COPS) and the Workload Information System (WIS) for OPS costs
- F&E funding baselines as of June 1998
- Software Life Cycle Model (SLIM) estimates.

These sources were used as departure points for cost analyses to estimate life-cycle R,E&D, F&E, and OPS funding from 1998 through 2015. If a project changes significantly or if a new project is created, estimates will be derived using the best data and estimating tools available.

Estimates for programs that have been included in the current FAA financial baseline are expected to be at least 80 percent accurate. Estimates for new programs without approved baselines are less accurate. In other words, for programs without approved baselines, the actual costs will be lower than the estimate about half the time and higher than the estimate about half the time.

13.4 Watch Items

The ability to meet FAA funding projections.

13.5 Summary

The NAS Architecture Version 4.0 was developed to stay within the FAA's January 1998 funding projections. This modernization plan has identified all necessary funding needs for R,E&D, F&E, and OPS from 1998 through 2015. NAS modernization costs include training, procedures development, regulation changes, and certification requirements. The primary cost is for air traffic management services, which includes improvements in safety, capacity, security, and environment. AIP funding is not included in the architecture cost profiles; however, user avionics costs are included. Cost estimates are based on recognized industry practices.